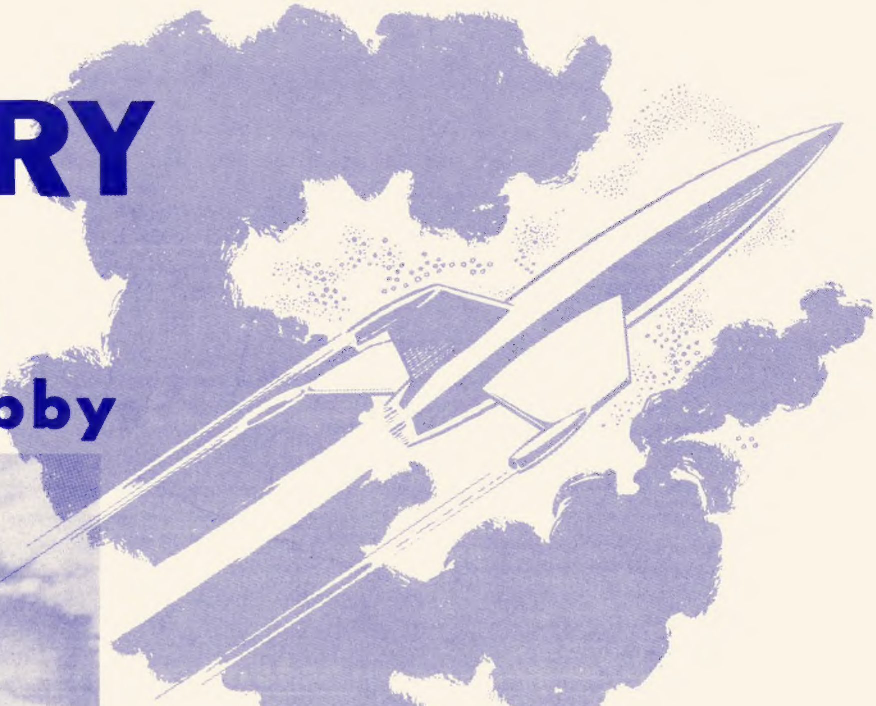
MODEL ROCKETRY

The Educational Space-Age Hobby



NAR Photo

Daily our newspapers, radio and TV stations feature stories telling of new developments in the field of rocketry. We hear of new shots into outer space, new fuels, new guidance systems and new discoveries in medicine. Every day space becomes a more important part of our lives as we learn more about our world and the universe beyond.

Countless young people of today's world look forward with great anticipation to the new developments tomorrow will bring. Will we inhabit the moon? To what extent is radiation a hazard? Is there life on other planets? What new engine can be perfected to carry our scientists to outer space and new worlds?

The destiny of almost every great engineer, scientist, physicist, mathematician and chemist was started early in life. In his youth he was encouraged in his special field by a free pursuit of his own interests. When those interests fall in the field of rocketry and its associated scientific fields, model rocketry satisfies a special need for the young rocketeer's development and enjoyment. The principles of rocket design, acceleration, thrust, aerodynamics, stability, trajectory, tracking and many other fields are identical for model rocketry and professional rocketry. Through model rocketry much scientific knowledge is gained by the young rocketeer to enrich and supplement his normal academic studies.

Many youngsters and adults do not plan to become engineers or scientists. They are looking for an inexpensive hobby which offers pleasure, relaxation, excitement and competition. The sport of model rocketry is their choice. The fascination of this hobby can well be appreciated when it is realized that a small home built rocket weighing from a fraction of an ounce to only a few ounces can travel at speeds of several hundred miles per hour and attain altitudes of over 2,000 feet. Not only is it possible to achieve this fantastic performance but the same rocket can be built to return safely for many additional flights.

The growing interest in model rocketry is shown in the development of clubs, organizations and teams for group participation in the field of model rocketry. The hundreds of model rocket clubs in this country alone demonstrate the popularity of this space-age hobby. Through their organizations model rocketeers have developed systems of classification for their models and rules for competitive events. Safety rules and procedures established by model rocketeers stand among the best for any sport or hobby. In just a few years since its inception model rocketry has become a major national hobby and is spreading out to other lands.

ASTRON ROCKET SOCIETY SAFETY CODE

As a model rocketeer I will act in a mature manner with safety foremost in my mind in all my model rocket activities and will obey this safety code at all times.

1) I will not attempt to compound propellants or other combustible chemicals or tamper with pre-manufactured rocket engines. I will inspect each rocket engine before use and never use an engine which shows signs of physical damage, remembering that any rocket propellant can be explosive under certain conditions.

2) I will not smoke near rocket engines, launch my rockets in the presence of highly combustible materials, or engage in any activity which would present a fire hazard.

3) I will never use any metallic rocket engines, will not construct my model rockets with substantial metal parts in the area of the engine, and will not launch any rocket over 16 ounces in weight or containing more than 4 ounces of propellant in compliance with Federal regulations.

4) My model rockets will be electrically ignited, using a launch system with either a switch protector or a safety interlock to prevent accidental ignition of the rocket engine, and I will remain at least 10 feet away from any rocket which is being launched.

5) I will launch my model rockets using a launching rail or other suitable guide means aimed within 25 degrees of the vertical to assure a safe and predictable flight path, and will launch only rockets whose stability characteristics have been predetermined.

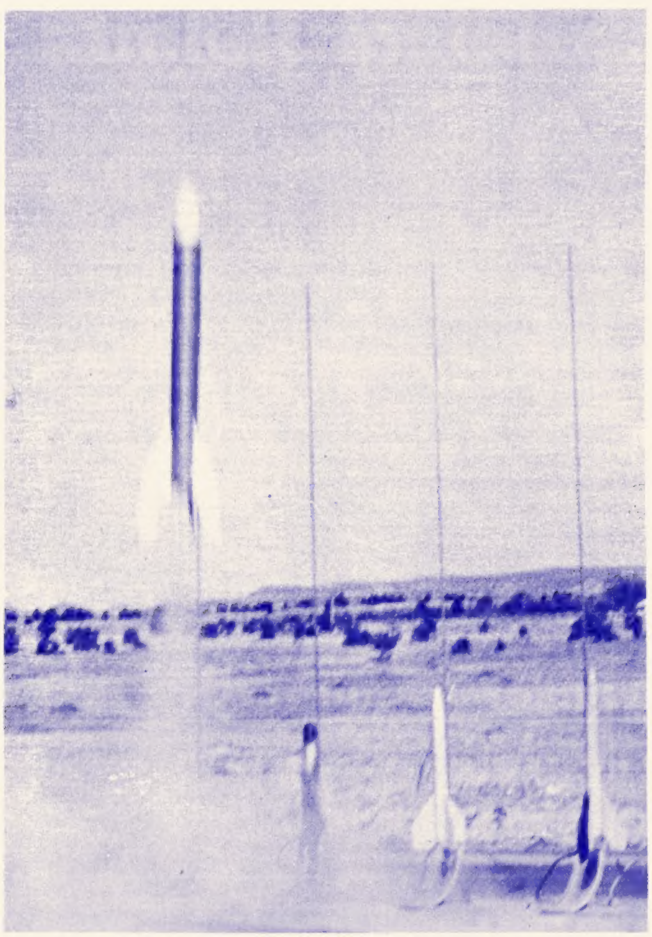
6) I will not fly model rockets in high winds, conditions of low visibility, in the vicinity of low flying aircraft, near tall buildings, near people not aware of the launching, or under any conditions which might endanger property or persons.

7) I will not launch rockets so that their ballistic trajectories will carry them against targets on the ground and will never use an explosive warhead in a rocket.

8) My model rockets will contain recovery devices which will deploy at an altitude of at least 50 feet to return the rocket safely and undamaged.

9) To prevent accidental eye injury I will always either place the launcher so the end of the rod is above eye level or cap the end of the rod with my hand when approaching it.

10) I will launch my model rockets with adult supervision and will remember that the safety of myself and others depends on my own actions.



Model Rocketry

Why is model rocketry today as safe as flying model airplanes, playing golf, boating or swimming? One of the most important reasons is the availability of commercially made rocket engines.

Commercial engines are built completely free of all metal parts. They are extremely reliable, are less expensive and will out-perform anything the rocketeer could attempt to build himself. Each engine is a cylindrical unit which fits easily into the rocket and is replaced in its entirety after each flight. The model rockets illustrated here are all designed to use only commercial engines.

Each engine is simply constructed. It consists of a tubular body, nozzle, propellant charge, delay charge, ejection charge and paper end cap. Estes Industries, Inc. manufactures and sells these propellant devices. They are also available through hobby stores in many localities.

Types of Rockets

Most model rockets are easily constructed at home. This booklet contains plans and technical information on some of the basic design types which are popular among model rocketeers. The beginning modeler will do well to follow instructions exactly at first, leaving variations of basic designs for later experimentation as his knowledge increases. Materials for building the rockets in this book are available in hobby shops which carry Estes rocket supplies or may be ordered directly from Estes Industries.

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Before starting construction of your model rocket, study carefully these general instructions as well as the instructions for the particular type of rocket you wish to make.

Metal should not be used in any part of the construction of model rockets. It is more dangerous and heavier than paper or balsa wood as well as more expensive.

BODY TUBES: Although several sizes of body tubes are commercially available, it may sometimes be necessary for the rocketeer to roll his own to fit a certain design. Almost any kind of paper will be suitable, although a bond paper is generally the easiest to work with. Apply an even layer of hard drying paper glue or paste (flour and water make a suitable paste) and wrap tightly around the proper size mandril. A wood dowel, metal rod, tubing, etc. will make a suitable mandril. Always remove the tube immediately after wrapping.

NOSE CONES: Certain rocket designs demand that the rocketeer make his own nose cones. These nose cones can be built from almost any type of wood or soft plastic, but not metal. A rounded nose cone is safer than a pointed one, and performs better at the speeds the model rocket will travel.

Nose cones can be turned on a lathe, but generally a more satisfactory result may be obtained by drilling a ¼ x 1 inch long hole in the base end of 1" x 1" balsa nose cone stock. Glue into the hole a two inch length of ¼" hard wood dowel. After the glue has dried, chuck the dowel into a high speed electric drill. Then sand the balsa block to the desired shape using a fine grit sand paper. When the nose cone has been shaped, cut off the protruding dowel. Balsa stock as well as finished plastic and balsa cones are available from Estes Industries.

FINS AND STABILITY: Sheet balsa either 1/16" or 3/32" thick makes ideal material for stabilizing fins. Cut the fins from the balsa sheet using a sharp knife. For the best design in finishing the fins the leading edges should be rounded, and the trailing and outermost edges should be sanded to a long tapered knife edge. In most rocket designs the fins should be as large as possible and as light in weight as possible. Fins must be carefully aligned and securely glued to the rocket body. Stabilizing fins should always be placed as far to the rear of the rocket as possible. Never place any fins on a model at any point in front of the center of gravity. (The center of gravity of a rocket is the point along the body at which the rocket will balance on a knife edge with an engine in place.) For a rocket to fly, the center of gravity with the engine installed must be ahead of the center of pressure by at least one-half the diameter of the rocket body. (The center of pressure is determined approximately as the point about which a cardboard cut-out of the minimum view area of the rocket will balance on a knife edge.) The farther the center of gravity is ahead of the center of pressure the greater will be the stability and the better the rocket will fly.

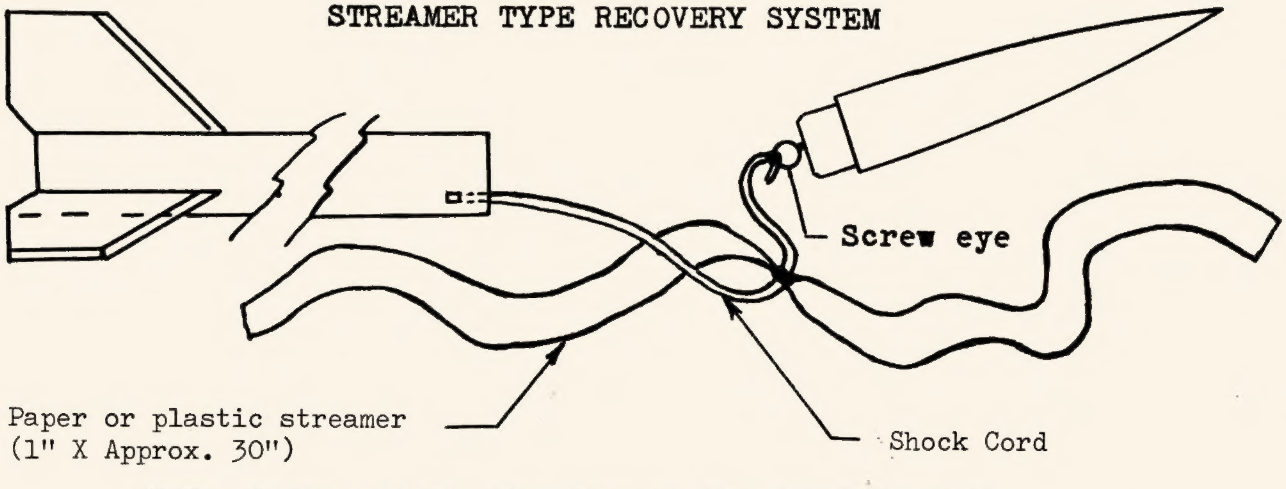
RECOVERY SYSTEMS: A recovery system constitutes any means of causing the rocket to return to earth in a non-streamlined and safe manner. There are several suitable systems employed today, three of which are described below. They are the streamer ejection system, the blowing off of a removable set of fins, and the breaking up of the aero-dynamic stability by shifting of the center of gravity behind the center of pressure. Although the principle of this last system is more difficult to understand, it is cheaper and simpler to build and easier to operate. Its zero weight permits the construction of a rocket of extremely light weight and high performance.

PLANS

The streamer type of recovery system (see fig. 1) depends upon a paper or plastic drag member being blown out of the nose end of the rocket when it reaches its peak altitude. The nose cone and streamer are ejected from the rocket by an ejection charge contained in the motor. The streamer must be protected from the ejection charge by being completely wrapped with a suitable piece of paper. The nose cone, body and streamer are held together by a shock cord, generally model airplane contest rubber. The shock cord must be anchored solidly at its ends to the nose cone and body tube to prevent separation at ejection and resulting damage to the rocket. Plan No. 1 makes use of this system.

FIGURE 1.

STREAMER TYPE RECOVERY SYSTEM

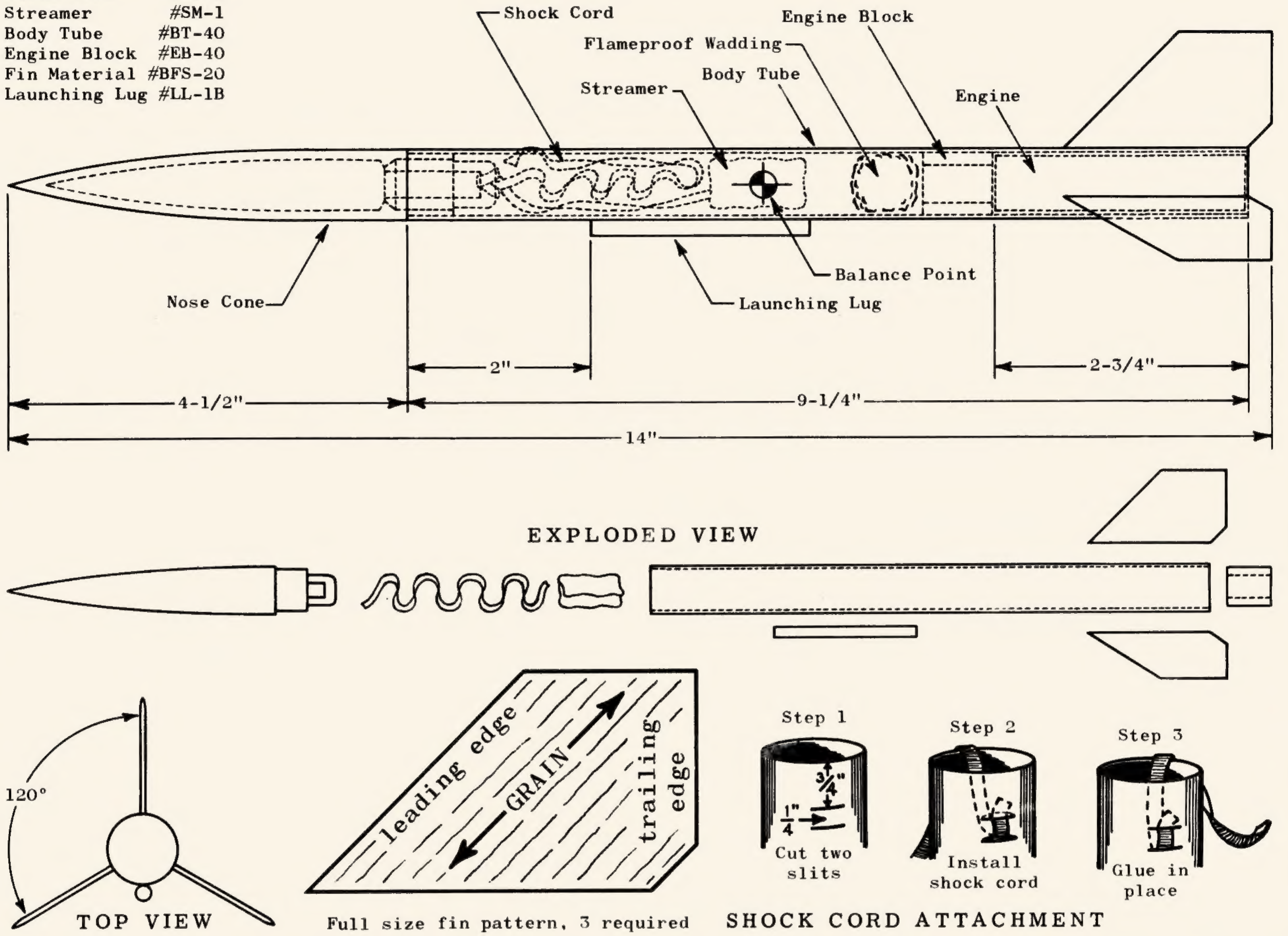


NOTE: Before placing the streamer into the body of the rocket it must be completely protected from the ejection charge with a suitable paper wrapper.

The Arrow-C
Plan No. 1

PARTS LIST

Nose Cone	#PNC-40G
Shock Cord	#SC-1
Streamer	#SM-1
Body Tube	#BT-40
Engine Block	#EB-40
Fin Material	#BFS-20
Launching Lug	#LL-1B



Full size fin pattern, 3 required

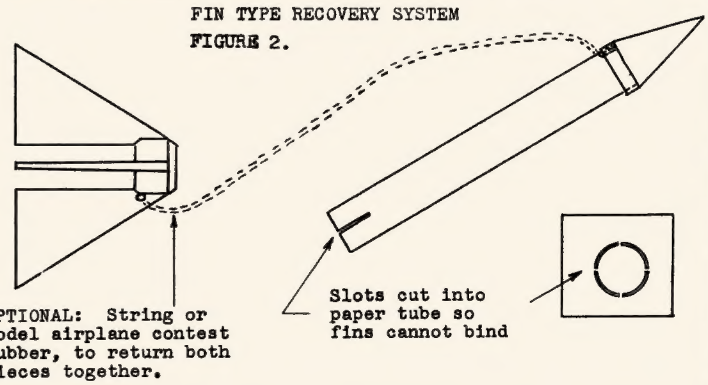
SHOCK CORD ATTACHMENT

Care should be taken in building the Arrow-C model rocket to be sure the balance point is at least as far forward as indicated in the plans. Additional weight may be added to the nose to shift the balance point forward if necessary. The plan shown here is of the original Arrow-C. If a wood nose cone is used, it may be rounded to increase safety and performance. As the rocketeer progresses in the art of model rocketry he will be able to deviate considerably from the plans presented here in building rockets of his own design. Remember in constructing the Arrow-C or similar rockets that the nose cone must fit loosely enough to permit the ejection charge in the engine to easily blow off the nose cone and streamer.

The second type of recovery system shown in Fig. 2 employs a removable tail section. The fins can either separate completely from the rocket body or the two pieces may be held together by a nylon string or shock cord. This general type of design is quite popular for spot landing contests.

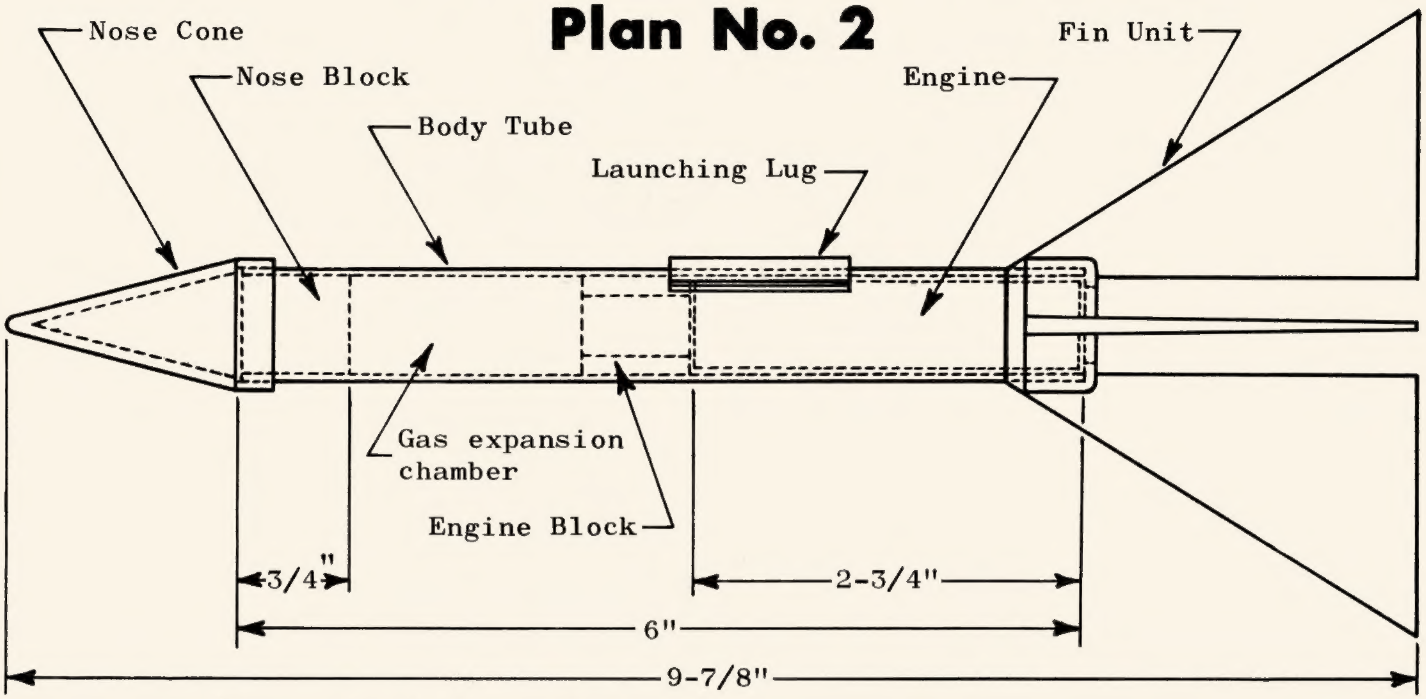
FIN TYPE RECOVERY SYSTEM

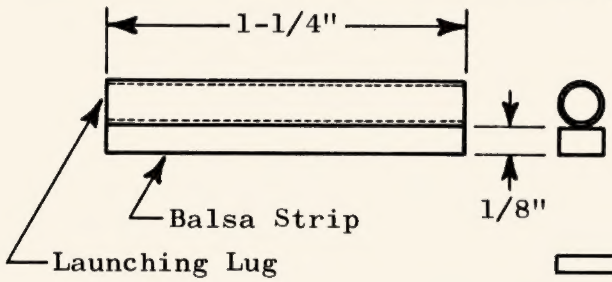
FIGURE 2.



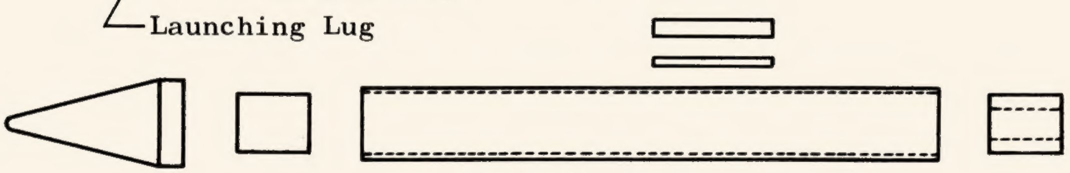
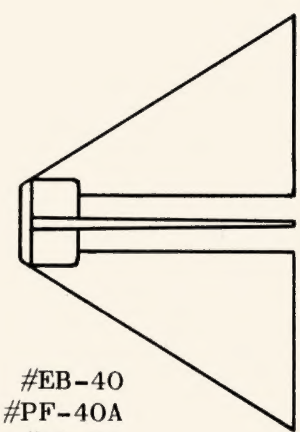
The Sky Bird

Plan No. 2

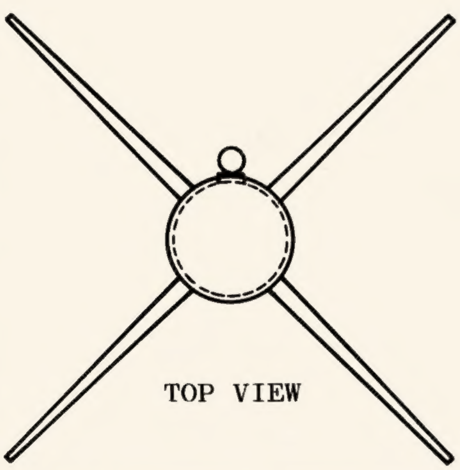




LAUNCHING LUG
DETAIL

EXPLODED VIEW



TOP VIEW

PARTS LIST

Nose Cone	#PNC-40F	Engine Block	#EB-40
Nose Block	#NB-40	Fin Unit	#PF-40A
Body Tube	#BT-40	Launching Lug	#LL-1A

Launching lug is glued to a 1/8" x 1/8" x 1-1/4" piece of balsa and the balsa glued to the body tube to space the lug so the launching rod will fit in the lug without binding on the plastic nose cone and fins. The hollow engine block allows the ejection charge to pressurize the forward chamber thus reducing the shock of ejection. Both engine block and nose block must be securely glued in place. Fin unit must make a tight friction fit on the rear end of the body so it will not come off under acceleration.

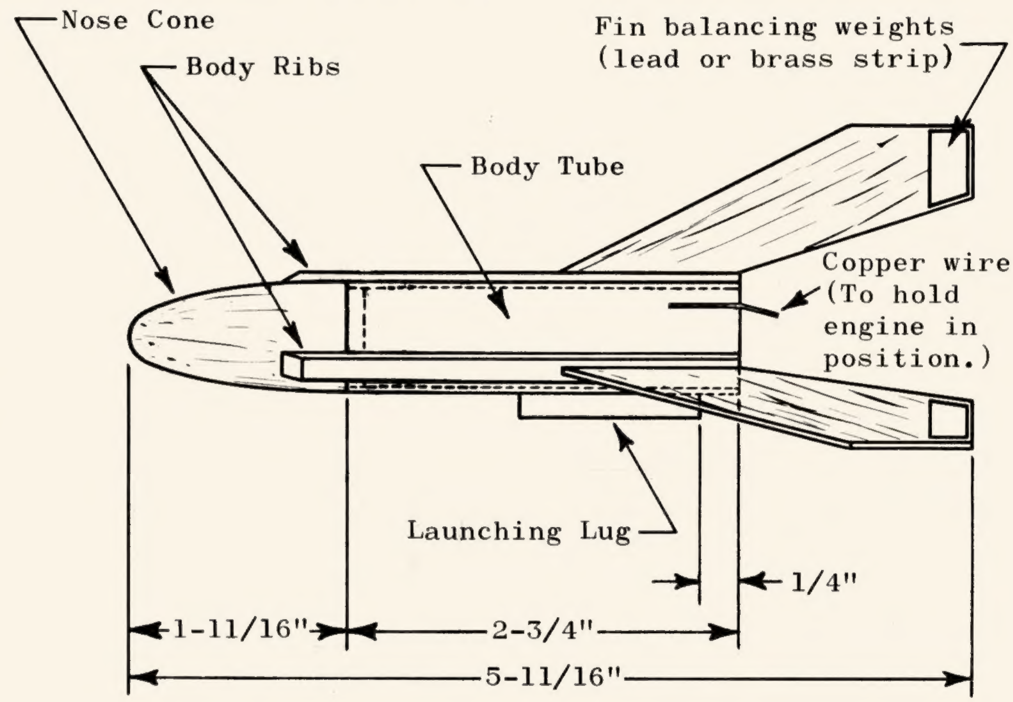
Rocket plan No. 2 makes use of the removable fin type recovery system. All parts on this rocket are sold by Estes Industries, Inc., or the rocketeer can make all of the parts except the plastic fins himself. The large fin area of the Sky Bird places the center of gravity sufficiently ahead of the center of pressure so that the bal-

ance point of this bird is not critical. Care should be exercised to make sure the fins fit sufficiently well so the rocket, upon fast acceleration, will not run off and leave the fins, but loosely enough so that the fins can be easily parted from the rocket body by the ejection charge in the motor. This recovery system is not recommended for use with series II engines.

The third method of recovery system which is accomplished by shifting the center of gravity requires that very careful consideration be given to the balance of the rocket. The engine must sit as far forward as possible. When the engine is in place it will add weight to the nose of the rocket, and when it is expelled at the end of the upward travel of the rocket, weight is removed from the nose and the center of gravity is shifted backward toward the fins. This puts the center of gravity behind the center of pressure and causes the rocket to return in a tumbling fashion. Plan No. 3 below makes use of this principle.

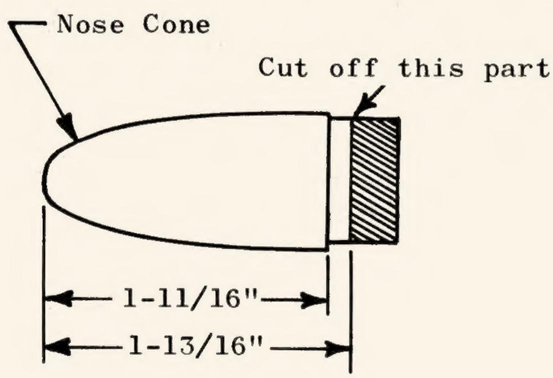
The Orange Bullet

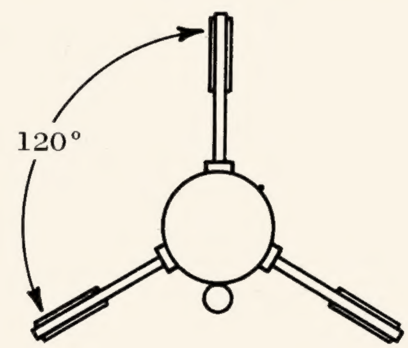
Plan No. 3



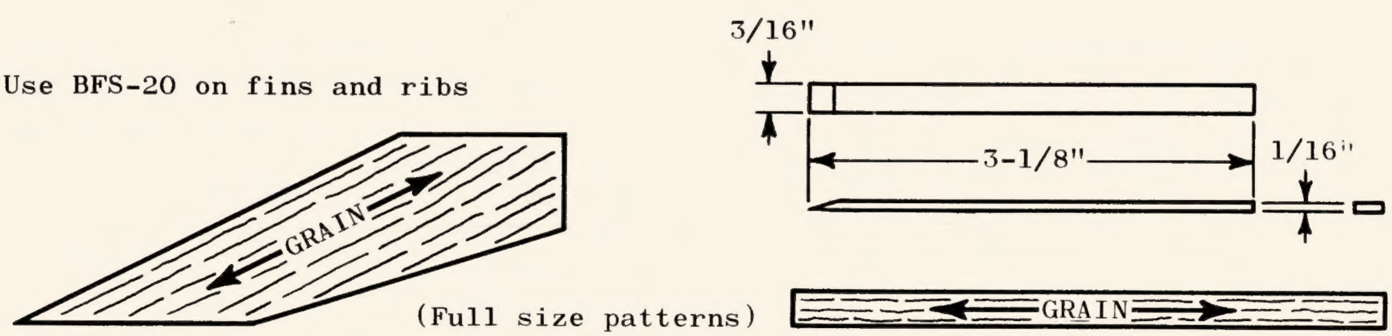
PARTS LIST

Nose Cone #BNC-20B
Body Tube #BT-20J
Fin Material #BFS-20
Launching Lug #LL-1A
Short copper wire
Lead or brass balancing weights





Use BFS-20 on fins and ribs

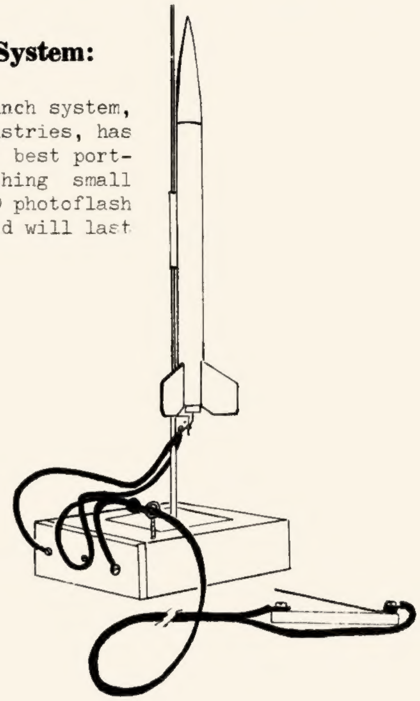


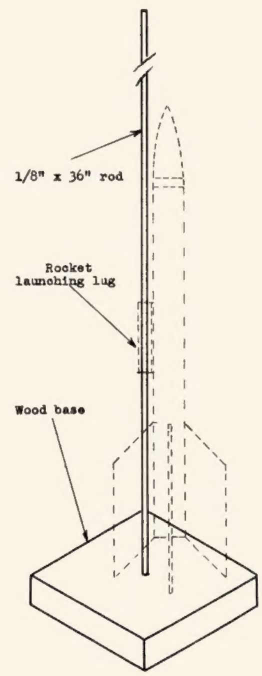
When this rocket is completed it should weigh approximately ¼ ounce without the engine installed. Enough weight is added to the tips of the fins to barely make the rocket unstable for its return flight. The proper weighting can be determined by throwing the motorless rocket into the air and noting the manner in which it falls. Add additional weight until the rocket does not fall nose first. If too much weight is added to the end of the fins it will cause the rocket to be unstable in its upward flight. The rocket is weighted properly when it is just barely unstable without the engine in place. Extreme care must be given to the mounting of the engine in the rocket so that the slightest pressure will allow the engine to be expelled through the rear of the rocket body.

LAUNCHING SYSTEMS: Model rockets are stabilized by the air currents acting against their surface areas. In order for there to be any stabilizing effect the rocket must attain sufficient speed to cause the necessary air currents. For this reason, the rocket must be guided during its initial accelerating period. The type of rocket in plan No. 2 may be launched with a very short guide. This is due to its large fin area and high degree of stability. Rockets such as the ones shown in plans No. 1 and No. 3 require a greater velocity in order to become stabilized, thus they need a launching guide of greater length. Such a mechanism can either take the form of a launching rail or a tower. It should provide the guidance for a distance of 20" to 5' depending on the stability and acceleration factors of the particular rocket which is to be launched. The simplest launching guide consists of a 1/8" x 36" long piece of welding rod or music wire, (obtainable from your local hobby store) one end of which is set in a wood or concrete base. This system is illustrated in Figure 3. Commercially produced towers and launching rails are available, including the Electro-Launch produced by Estes Industries, which makes rocket launching somewhat more convenient. If a rod is used for launching rockets, it will be necessary to glue a launching lug to the body of the rocket. This lug can either be a piece of 5/32" x 2" aluminum tubing or a piece of plain soda straw which will fit loosely over the launching rod.

The Electro Launch System:

This complete Electro Launch system, available from Estes Industries, has proven to be one of the best portable systems for launching small models. Only four size D photoflash batteries are required and will last for over 50 launchings.

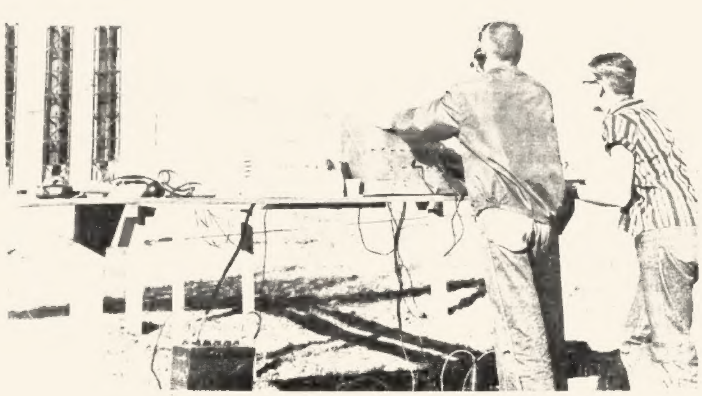




Rod launchers similar to the one shown here are the most commonly used type of launcher for model rockets. It consists of a ⅛" x 36" rod securely fastened to a wood base. A launching lug secured to the rocket body fits over the rod, thus providing a guidance means for the rocket during its initial flight.

The shapes and designs obtainable in model rockets are limited only by the scope of the imagination of the young rocketeer.

The range safety officer gives the all clear. A 10 second count down is given by the firing officer and with the press of a button the model streaks skyward. NAR Photo



Estes Industries Technical Report TR-1

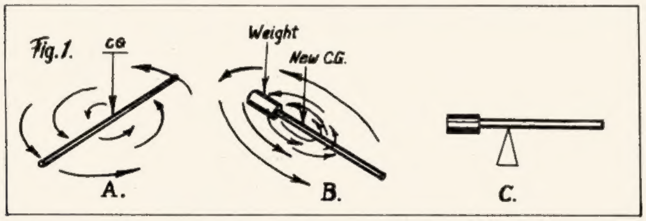
ROCKET STABILITY

by Vernon Estes

These reports are published as a service to its customers by Estes Industries, Inc., Box 227, Penrose, Colorado.

One of the first principles any rocket designer must learn is that unless a rocket has a complex electro/mechanical guidance system, it will fly only if its center of gravity (also known as center of mass) is far enough ahead of the center of pressure to allow air currents to act against the rocket causing a stabilizing effect.

From your science class or other scientific studies you have probably learned that if a rotating force is applied to a free body in space it will cause it to rotate around its center of gravity. As an example of this, you could take a wooden dowel or uniform stick about two feet long and toss it into the air so that it will rotate end over end (see Fig. 1, example A). You will notice that regardless of how you throw the stick, vertically or horizontally, hard or easy, it will always rotate about its center. If a weight is attached to one end of the stick and it is again thrown into the air it will rotate about a new location (Fig. 1, example B). This time the point about which it rotates will be closer to the weighted end. If you take the weighted stick and balance it across a sharp edge you will find that the point at which it balances (its center of gravity) is the same point about which it rotated when tossed into the air (Fig. 1, example C).

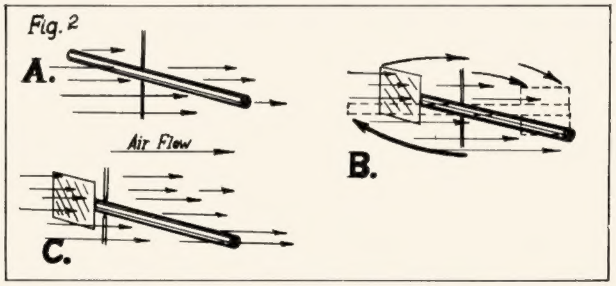


This simple explanation should aid you in understanding how a free body in space rotates around its center of gravity. A model rocket in flight is a free body in "space." If, for any reason, a force is applied to the flying rocket to cause it to rotate, it will always do so about its center of gravity.

Rotating forces applied to rockets in flight can result from lateral winds, air drag on nose cones, weights off-center, air drag on launch lugs, crooked fins, engine mounted off-center or at an angle, unbalanced drag on fins, unequal streamlining, etc. Obviously, some of these factors are going to be present in all rockets. Therefore, since rotating forces will be present, your rocket must be designed to overcome them. If your rocket is not so designed it will loop around and go "everywhere," but end up going nowhere. Nearly all model rockets are stabilized by air currents. By stabilized, we mean that all rotating forces are counteracted or overcome. This means that for each force trying to make the rocket rotate we must set up an equal and opposite force to counteract it.

How is this accomplished? Ask any rocket expert and he will simply say to design the rocket so the center of gravity is ahead of the center of pressure. From studying our first experiment it is easy to see how we could find the center of gravity by simply balancing the rocket on a knife edge as shown in example A of Fig. 3. But what and where is the center of pressure? The following experiment should aid you in understanding more about the center of pressure of a rocket.

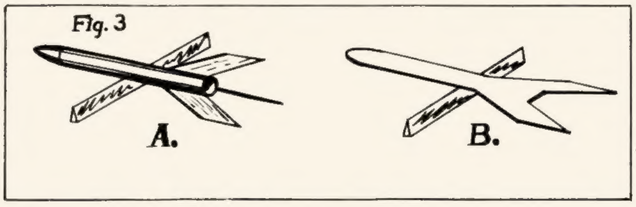
Suppose we take the same 2 foot long piece of dowel used in our first experiment and place it on a low friction pivot as shown in example A of Fig. 2. (The low friction pivot consists of two needle points held rigidly in place on opposite sides of the object by a heavy wire or board framework. The needle points are placed against the object just tightly enough to hold it, without interfering with its rotating on the axis created between the two points.) Then suppose the dowel is held in a uniform air current (wind) of 10 to 15 miles per hour. If the pivot has been placed in the center of the dowel and if the dowel is uniform in size (area) the forces exerted by the air pressure will be equal on both sides of the pivot and the air current will produce no rotating effect. In this condition the center of gravity and the center of pressure will be at the same point.



If, however, a vane of 3" x 3" cardboard is glued to one end of the dowel and it is again put into the air stream with the pivot in the same position, the moving air current will exert the greatest force against the end of the dowel which has the vane attached to it as in example B of Fig. 2. This will cause the dowel to rotate until the end away from the vane points into the wind. If we now move the pivot closer to the vane end of the dowel we will be able to locate a point along the dowel where equal air pressure will be applied to both ends. The air current will no longer cause any part of the dowel to point into the wind. This point is called the lateral center of pressure. Remember, the lateral center of pressure has to do only with the forces applied to the surface directly by air currents, and the larger the surface the greater the forces will be.

The ideal way to find the lateral center of pressure of a model rocket is to suspend the rocket between pivots as was done with the 2 foot dowel in Fig. 2, and hold the rocket in a uniform lateral air current. This can be accomplished to some degree of accuracy by holding the suspended rocket in a breeze of 10 to 15 m.p.h. The same effect can be accomplished very accurately by the use of a low velocity wind tunnel. However, since most model rocket builders and designers do not have wind tunnels and low friction pivots as described above, other methods must be provided for determining the center of pressure.

Keeping in mind the fact that the air pressure applied to a surface is proportional to the area of the surface, it then becomes possible to approximate the rotating effect of the action of the air pressure by making a uniform area cutout of your rocket and locating the balancing point of this cutout. To make this cutout, simply lay your rocket over a piece of cardboard and mark around the edges. Next, cut around the lines and balance the cutout on a knife edge as shown in example B of Fig. 3.



This method will determine the lateral center of pressure (the center of pressure with the air currents hitting the rocket broadside). If the rocket is designed so the lateral center of pressure is 1/2 the body diameter (1/2 caliber) behind the center of gravity it will have ample stability under all reasonable conditions. If, however, the rocket's fins are very crooked, set at opposing angles, or if the rocket uses a disc or cone for stabilizing, the lateral center of pressure should be set at least one diameter behind the center of gravity.

In flight, of course, the rocket will not be traveling sidewards, but with its nose pointed into the wind. With the model's nose pointed into the wind, the location of the effective center of pressure will be affected by the shape of the fins, the thickness of the fins, the shape of the nose cone, location of the launching lug, etc. With most designs this shift is to the rear, adding to the stability of the rocket.

Suppose a model rocket starts to rotate in flight. It will rotate around its center of gravity. When it turns the air rushing past it will then hit the rocket at an angle. If the center of pressure is behind the center of gravity on the model, the air pressure will exert the greatest force against the fins. This will counteract the rotating forces and the model will continue to fly straight. If, on the other hand, the center of pressure is ahead of the center of gravity the air currents will exert a greater force against the nose end of the rocket. This will cause it to rotate even farther, and once it has begun rotating it will go head over heels in the air.

It is easy to see from this why it is best to build the rocket with its fins as far as possible to the rear. The farther behind the center of gravity the center of pressure is placed, the stronger and more precise will be the restoring forces on the model, and it will fly straighter with less wobbling and power-robbing side-to-side motion. Under no circumstances should fins be placed forward of the center of gravity on a model, as they will add to its unstability tendencies rather than help stabilize it.

When building high performance, light weight rockets, quite often a more precise method of determining the stability margin of the rocket is desired. While the experienced rocketeer will develop an ability to tell, by looking, approximately how stable a rocket will be, any rocket, once constructed, should be checked to determine whether or not it has sufficient stability to be safe in flight. The simplest, least expensive method of doing this requires only a string and some tape.

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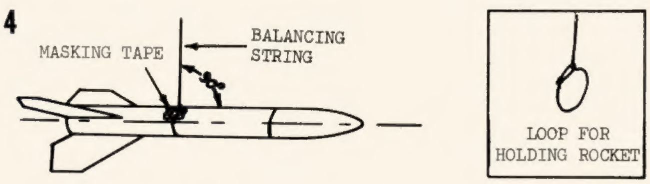

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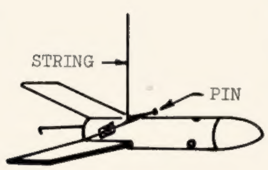
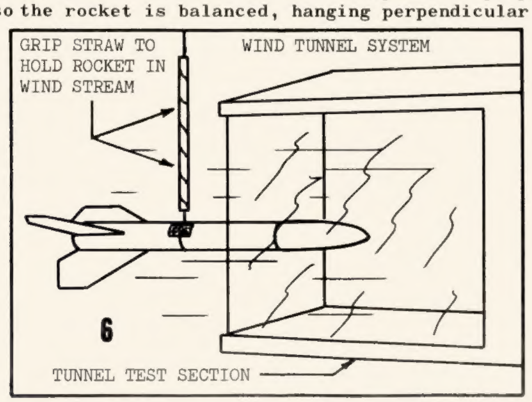


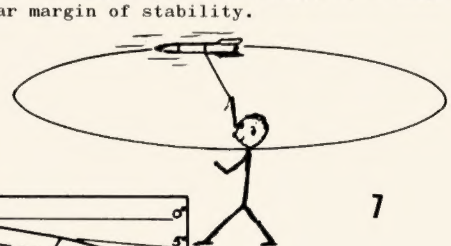
The rocket to be tested (with an engine in flight position: The center of gravity is always determined with an engine in place.) is suspended from a string as illustrated in Fig. 4. The string is attached around the rocket body using a loop as shown. Slide the loop to the proper position so the rocket is balanced, hanging perpendicular to the string. Apply a small piece of tape to hold the string in place. If the rocket's center of gravity (balance point) falls in the fin area, it may be balanced by hooking the string diagonally around the fins and body tube as shown in Fig. 5. A common straight pin may be necessary at the forward edge of one of the fins to hold the string in place. This string mounting system provides a very effective low friction pivot about which the rocket can rotate freely.

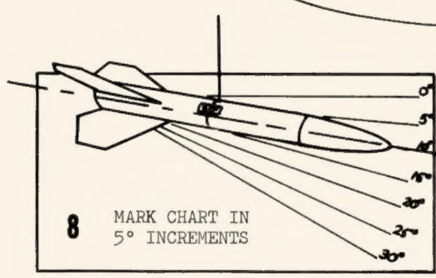


For the first system slide a soda straw along the string to a position just above the rocket. Then suspend the rocket in a low velocity air stream (wind tunnel or gentle breeze), with the nose of the rocket pointing into the wind, and then turn the rocket approximately 10° out of the wind to see if it recovers. If so, the rocket is stable enough for flight.

The second method involves swinging the suspended rocket overhead in a circular path around the individual, as shown in Fig. 7. If the rocket is stable, it will point forward into the wind created by its own motion. If the center of pressure is extremely close to the center of gravity, the rocket will not point itself into the wind unless it is pointing directly forward at the time the circular motion is started. This is accomplished by holding the rocket in one hand, with the arm extended, and then pivoting the entire body as the rocket is started in the circular path. Sometimes several attempts are required in order to achieve a perfect start. If it is necessary to hold the rocket to start it, additional checks should be made to determine if the rocket is flight-worthy.

Small wind gusts or engine misalignment can cause a rocket that checks out stable when started by hand as described above to be unstable in flight. To be sure that the rocket's stability is sufficient to overcome these problems, the rocket is swung overhead in a state of slight imbalance. Experiments indicate that a single engined rocket will have adequate stability for a safe flight if it remains stable when the above test is made with the rocket rebalanced so the nose drops below the tail with the rocket body at an angle of 10° from the horizontal (see Fig. 8). With cluster powered rockets a greater degree of stability is needed since the engines are mounted off center. The cluster powered rocket should be stable when imbalanced to hang at 15° from the horizontal. Heavier rockets which accelerate at a lower rate require a similar margin of stability.





Caution should be exercised when swinging rockets overhead to avoid collision with objects or persons nearby. Velocities in excess of 100 miles per hour are possible. This is sufficient to cause injury.

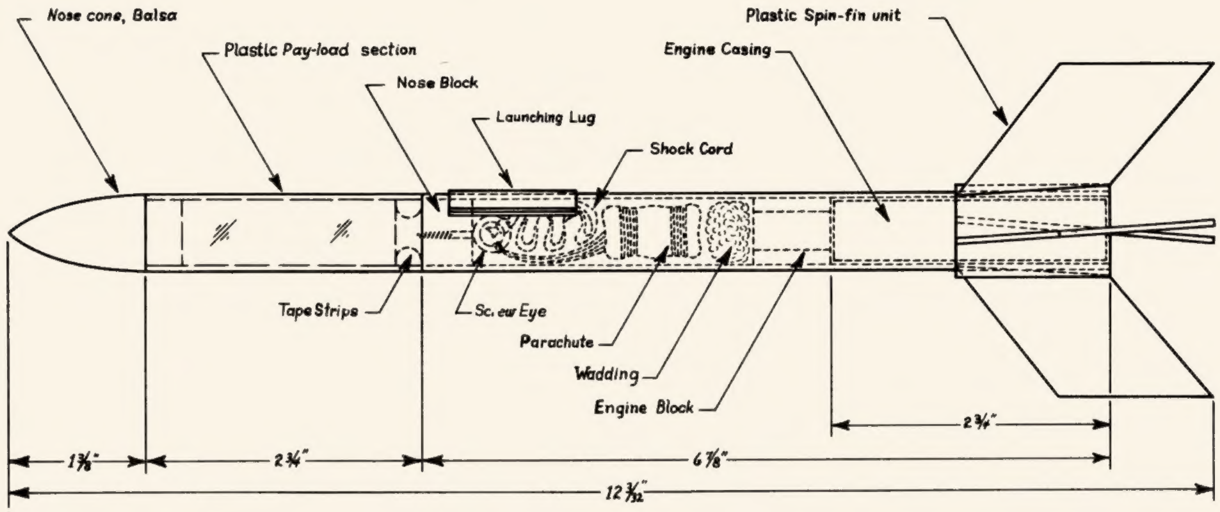
Suppose you construct a rocket and find that it will not be stable. Do not try to fly it. Corrections must be made. Tests have been made where the stability of the rocket was in question. If it was completely unstable it would loop around and around in the air, seldom reaching over 30 feet in height and never reaching a velocity in excess of 20 or 30 miles per hour. However, occasionally one of these rockets would make a couple of loops, suddenly become stable due to the lessening of the fuel load, and make a bee line straight into the ground. Had anyone been standing in the wrong place a serious injury could have resulted.

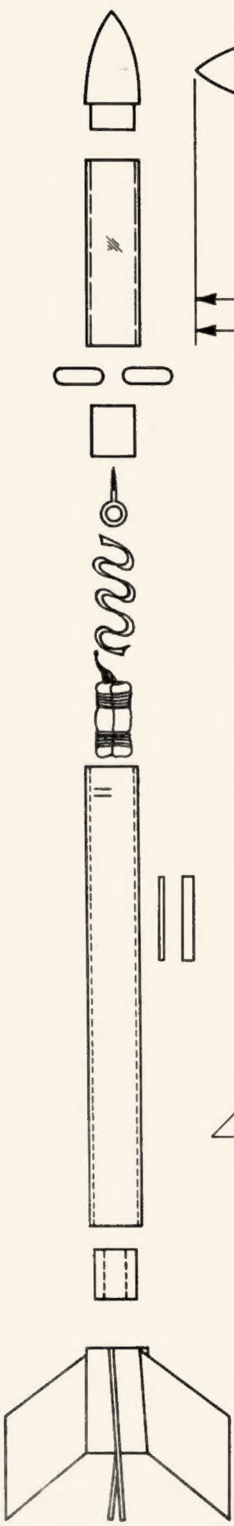
If a rocket does not show the degree of stability required for safety it can be easily altered to conform either by moving the center of gravity forward or by moving the center of pressure rearward. To move the center of gravity forward, a heavier nose cone is used or a weight is added to the nose of the rocket. To move the center of pressure rearward, the fins may be made larger or moved farther back on the body tube. With the Astron Scout rocket and many other designs, greater stability is obtained by constructing it so that a large portion of the fins project beyond the rear of the rocket body.

Estes Industustries Rocket Plan No. 4

BUG-A-BYE

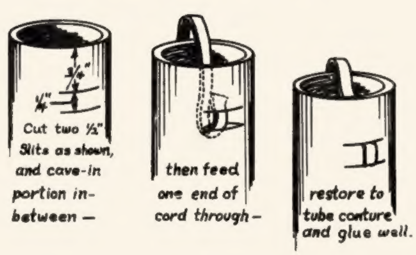
Payload Rocket

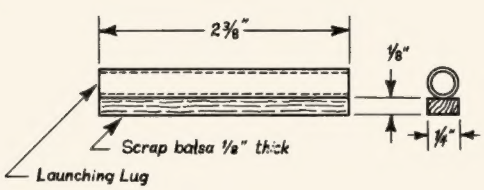


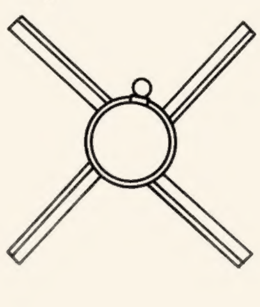


PARTS LIST	
1-Payload section kit	#PS-40A
1-Launching lug	#LL-1B
1-Shock cord	#SC-1
1-Parachute material	#PM-1
1-Body tube (Cut to length.)	#BT-40
1-Engine block	#EB-40
1-Fin set	#PF-40B

Shock Cord Installation







Assembly Instructions

Every commercial or military rocket is designed for a purpose--to carry a payload. The payload may be a camera, hydrogen bomb, mail sack, radio transmitter, animal or man. Regardless of the payload requirements, however, a rocket can be designed to do the job.

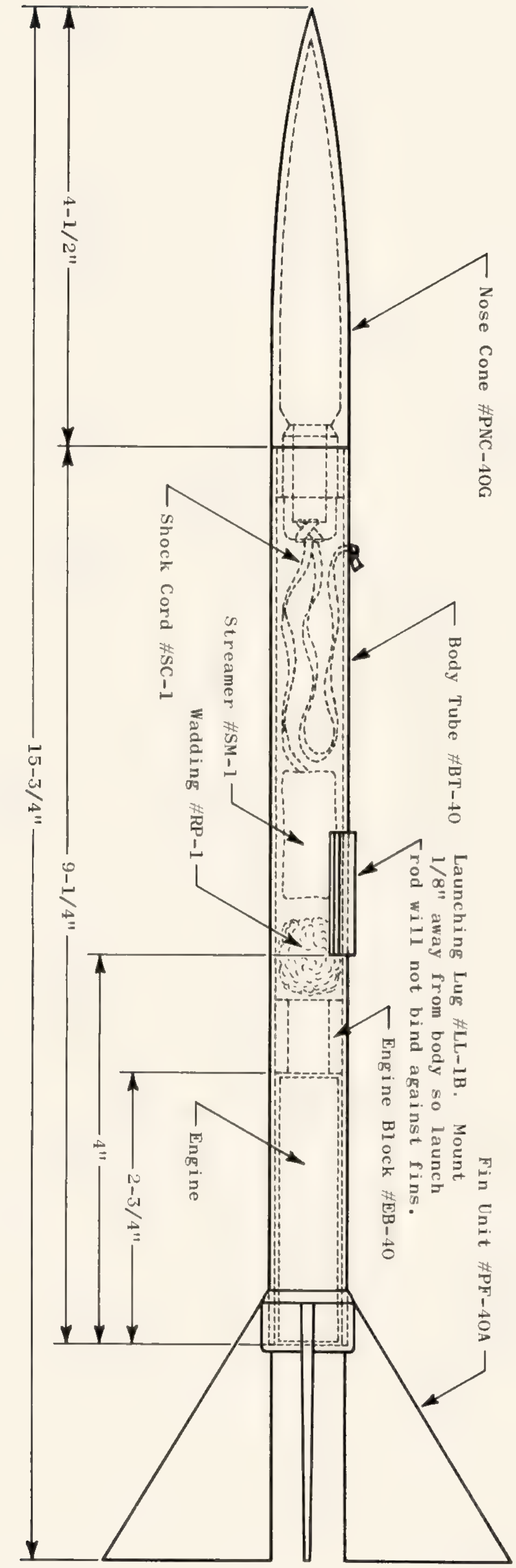
The BUG-A-BYE rocket has been designed for its special purpose, the study of the effects of acceleration on small objects, including biological specimens. When the BUG-A-BYE is launched with a Series II engine the acceleration can exceed 100 G's. If the average man were to be subjected to G forces of this nature he would weigh about 17,000 pounds. What effect would this have on other objects? You can do your own experimenting and find out.

The BUG-A-BYE rocket is easy to build. The complete rocket can be built from standard parts listed in our current catalog. For constructing the rocket it has been found that white glue is best.

First spread glue around the inside of one end of the body tube as far in as you can reach with your little finger. Then push the engine block into the end of the tube and push it forward until it is 2-3/4" from the end.(An engine may be used to push the block into place. Push in until the end of the engine is even with the end of the tube, then remove the engine immediately.) Do not pause during this operation or the engine block may become stuck in the wrong position.

Glue the launching lug in place as shown in the drawing. Assemble the payload section according to the directions that accompanied it. Attach the shock cord and recovery system as shown in the drawing. The fin unit should be attached as shown in our catalog. If you are using a Series II engine be sure the fins are secured very tightly. Under acceleration of 100 G's they will have 100 times their normal weight. If they should come off your rocket could be damaged, and someone could be hurt if it hit him. The nose cone should fit tightly. If it is too loose wrap its shoulder with tape to increase the diameter. The maximum payload weight for this rocket is one ounce.

Dirty Bird III



The Dirty Bird III, designed by G. Harry Stine, President of the NAR, is one of his favorites, as it is so very easy to fly and assemble. Here is how it is done. . .

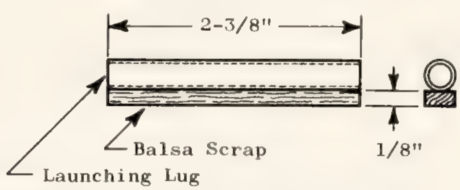
First cut a Body Tube 9 1/4" in length. Then glue the Engine Block in place at a distance of 2 3/4" from the rear of the Body tube (see illustration). To do this, place a large dab of glue on the end of your little finger. Reach through the end of the body tube and spread the glue around the inside of the tube as far forward as possible. Be very careful not to get any glue near the end of the tube. Insert the Engine Block in the end of the tube and using an engine casing push it forward until it is 2 3/4" from the rear. When inserting the Engine Block DO NOT STOP until it is in its proper position. Some glues set very quickly, and stopping for a moment may cause the block to set in the wrong place. Be sure to immediately remove the engine casing.

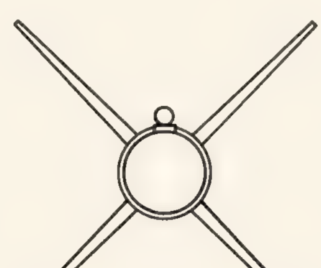
Punch a small hole in side of the Body Tube about 1" from the front end. Then tie a knot in one end of the shock cord, and put the other end down through the hole in the Body Tube. Reach in and pull the Shock Cord through until the knot comes up snug against the Body Tube. Place the Styrene Insert into the Nose Cone and tie the middle of the Shock Cord to the eyelet. Use a tape disc to attach the other end of the Shock Cord to a 12" length of streamer material. Carefully align and glue the Launching Lug to the side of the Body Tube about half way along the tube. After placing an engine in the end of the Body Tube, put on the tail Fin Unit. To assure a tight friction fit, it may be necessary to wrap the end of the Body Tube with scotch or masking tape.

The Dirty Bird flys best with "B" type engines (B.8-4 and B 8-5). The A.8-3 is fine if you have a limited flying area or don't want too much performance. Make sure the Fins fit very tightly when you use the B 3-5 engine.

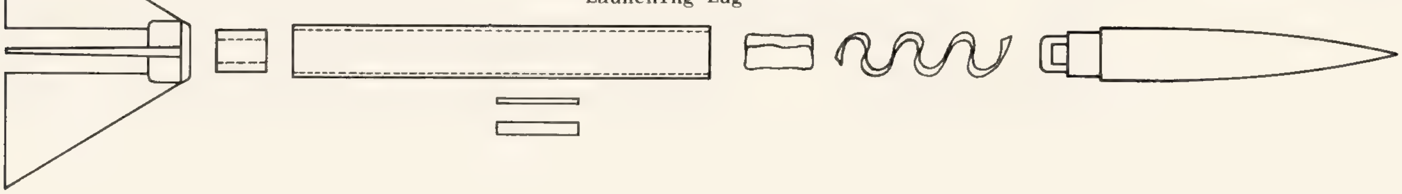
PARTS LIST

Plastic Nose Cone	# PNC-40G
Body Tube	# BT-40
Shock Cord	# SC-1
Streamer Material	# SM-1
Plastic Fins	# PF-40A
Engine Block	# EB-40
Launching Lug	# LL-1B





Top View



Estes Industries Technical Report TR-2

MULTI-STAGING

by Vernon Estes

These reports are published as a service to its customers by Estes Industries, Inc., Box 227, Penrose, Colorado.

Multi-staging is one of the most prominent characteristics of modern rocketry. This technique is used with solid propellant rockets and liquid propellant rockets, in rockets less than a foot tall and in rockets which tower to over one hundred feet. Multi-stage rockets are used to send up payloads from ants to humans to 500 feet, into orbit, and on to other planets.

The performance necessary for high orbits, moon shots and interplanetary probes is provided by multi-stage rockets. The principle advantage of multi-staging is the elimination of unnecessary weight in the later portions of the rocket's flight. For example, compare two rockets weighing 1500 pounds at takeoff, one a single stage missile and the other a two stage rocket. The single stage rocket holds 1000 pounds of fuel inside a 500 pound body while the two stage rocket consists of two 250 pound bodies, each carrying 500 pounds of fuel. When half the fuel in the single stage rocket is used there is still another 1000 pounds for the remaining half of the fuel to carry. On the other hand, when half the total fuel load of the two stage rocket is used the stages separate, leaving 250 pounds of dead weight behind, with only 750 pounds for the remaining half of the fuel to move. This weight saving is even greater at burnout when the single stage rocket weighs 500 pounds and the multi-stage rocket only 250.

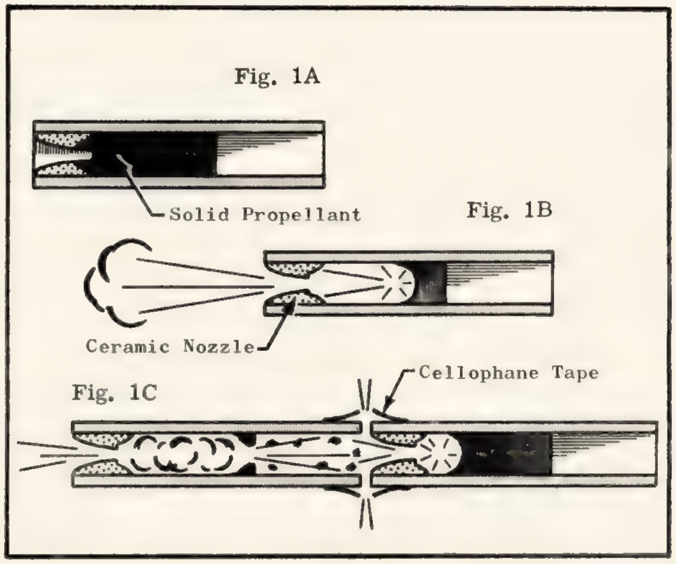
The principles of model rocketry and professional rocketry are identical although the model rocketeer uses somewhat different operating methods than the professional. The young rocketeer who masters the principles of multi-staging is gaining knowledge which he will find useful in his future career.

IGNITION

The lower or first stage of a multi-stage rocket is always ignited by standard electrical means. For further details, refer to the instruction sheet which is included with all rocket engines. The second stage ignition is accomplished automatically upon burnout of the first stage. As you will notice in figure 1A, the first stage engine has no delay or ejection charge. This is to assure instant ignition of the following stage upon burnout.

In figure 1B the propellant has been partially burned leaving a relatively large combustion chamber. As the propellant continues to burn, the remaining wall of propellant becomes thinner and thinner until it is too thin to withstand the high pressure inside the combustion chamber. At this point the remaining propellant wall ruptures, allowing the high pressure inside the combustion chamber to exhaust forward toward the nozzle of the next stage, carrying hot gases and small pieces of burning propellant into the nozzle of the second stage engine. This action is illustrated in figure 1C.

For this system to work, the rocket must be designed and built to make the best use of the operation of the engines. If the upper stage engine is simply placed



ahead of the booster engine so that the two can separate easily, ignition relaibility may fall as low as 40 percent, depending on the type of booster used (except when a Series II engine is used in the upper stage, in which case reliability will be about 80 percent). This unreliability in ignition is the result of several causes. First, when the forward propellant wall of the booster burns through, high pressure is built up in the area between engines. This pressure will force the stages apart. Second, the nozzle of the upper stage engine is quite small (.009 square inches in a Series I engine), making a difficult target for the hot gases and burning particles. Also, the nozzle of the upper stage will cool gases slightly as they enter it.

These problems in multi-stage ignition led to an extensive research program at Estes Industries. Revisions in engine design, gimmicks such as pressure relief vents, etc., were tried, but none proved satisfactory. What was needed was a method of controlling stage separation so that the hot ignition gases would have a proper chance to act on the upper stage engine before the upper and lower stages parted company.

After data on several hundred test firings had been collected, the problem was reanalysed to find the factors which contributed most to reliability. There were two: An extremely tight joint between stages and a coupling which forced the two stages to move apart in a completely straight line.

The simplest, most reliable method of joining stages ightly was immediately considered--tape. By wrapping one layer of cellophane tape around the joint between engines and then recessing this joint 1/2" rearward in the booster body tube, as in fig. 2, reliability suddenly jumped to almost 100%. Thus it was discovered that the coupling system played the most important part in multi-stage ignition reliability.

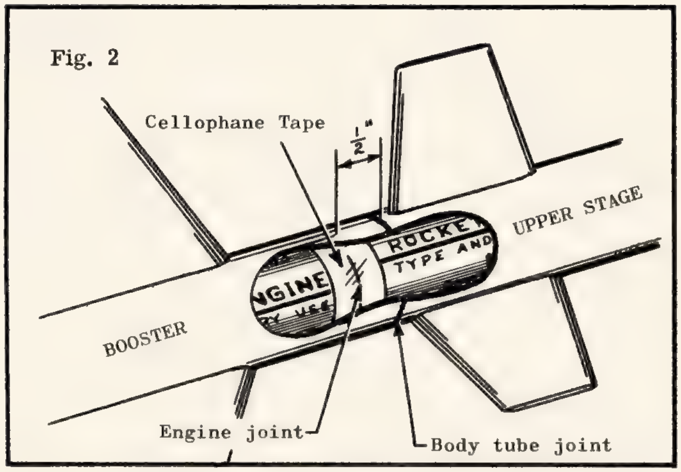


Fig. 2

STAGE COUPLING

We have already seen that the stage coupling must be tight and must allow the stages to move apart only in a straight line directly away from each other. This is to gain control over stage separation, preventing premature separation and incomplete separation. To understand just how tight this joint must be, wrap a single layer of 1/2" wide cellophane tape tightly around the joint between two engines as in fig. 3A. Then, grasping each engine firmly as in fig. 3B, pull them apart. If you repeat this a few times you will develop a "feel" for stage coupling which will prove very valuable when you build and fly multi-stage rockets.

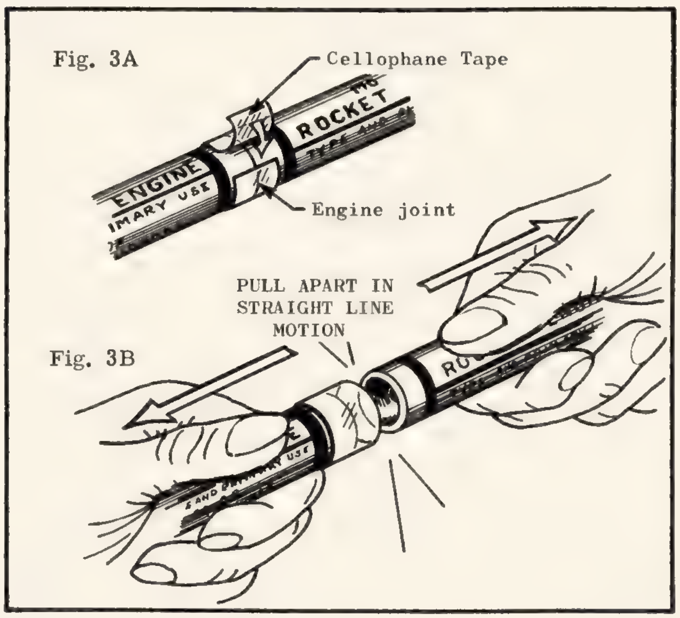


Fig. 3A

Fig. 3B

The proper coupling system to use in a rocket will depend on the size of the body tube. The coupling system for rockets using tubes of approximately 3/4" diameter (BT-20, BT-30, and BT-40) is shown in fig. 4. With this system the upper stage engine must project at least 1/2" rearward into the booster body tube to provide straight line separation. The engines are taped together before being inserted into the rocket. Check carefully before and after taping to be sure the engines are in their proper positions (nozzle of upper stage engine against top end of booster engine). Failure to check carefully can be highly embarassing as well as damaging to the rocket.

When the engines are taped together they can be inserted into the rocket. Wrap masking tape around the upper stage engine at the front and near the rear as in fig. 5 to give it a tight fit in the body and push it into place. Then wrap the booster engine and push the booster into position. Failure to get the upper stage engine in place tightly enough will result in the recovery system misfunctioning, while failure to get the booster on tightly can result in its dropping off under acceleration, leaving the entire engine unit dangling from the upper stage while the rocket loops around in the air.

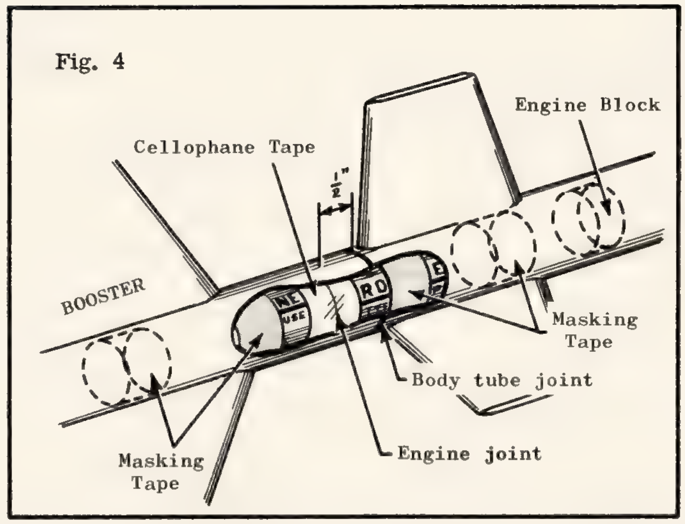


Fig. 4

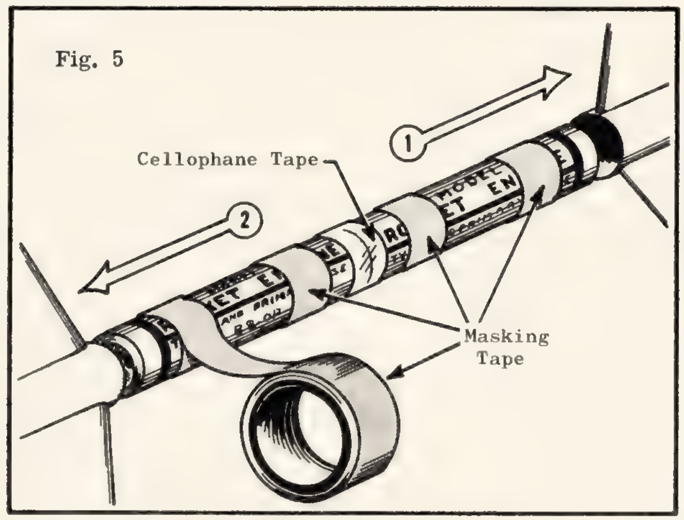


Fig. 5

The procedures used for two stage rockets should also be used on rockets with more stages. It is important, however, to get considerable experience with two stage rockets before attempting to design a 3 or 4 stage model.

Rockets using large diameter tubes (BT-50 and BT-60) require somewhat different methods, but the same principles of tight coupling and straight line separation must be followed. The recommended coupling method for larger diameter tubes is illustrated in fig. 6. The stage coupler is glued to the booster body tube, with the adapter for the upper stage engine mounting positioned forward to allow the stage coupler to fit into the upper stage, while the tube adapter in the booster is positioned to the rear.

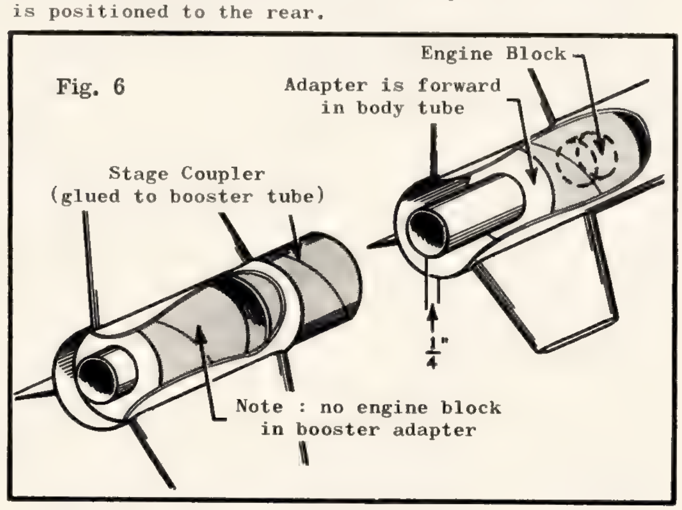


Fig. 6

The most satisfactory method of mounting engines in rockets with large diameter tubes involves positioning the upper stage engine holder tube to project 1/4" rearward from the end of the main body and positioning the engine block so the engine projects 1/4" rearward from the end of the engine holder tube (see fig. 7). This allows the engine to be held in place in its mounting by wrapping a layer of masking tape tightly around the end of the tube and the engine as in fig. 7B. The engine mounting in the booster must be built to leave space for this engine mounting (see fig. 7C).

Fig. 7A

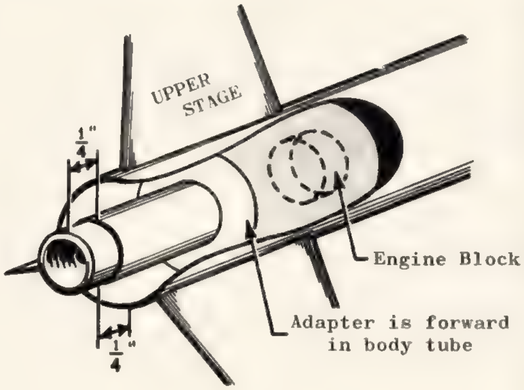


Fig. 7B

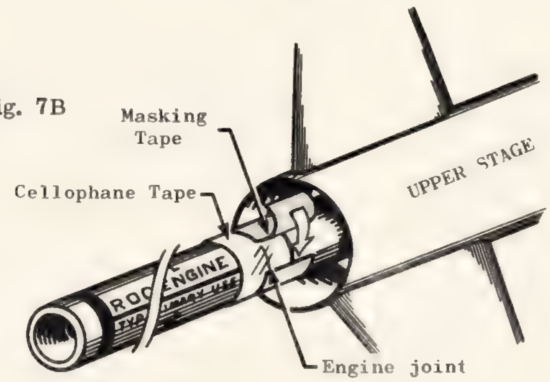
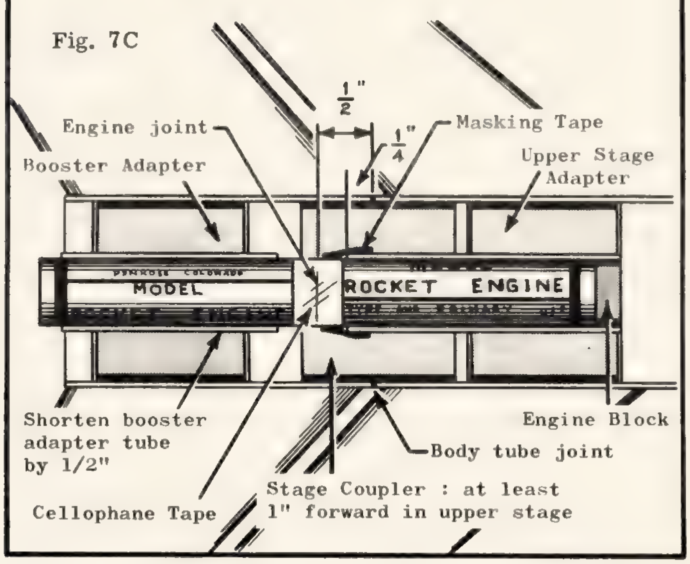
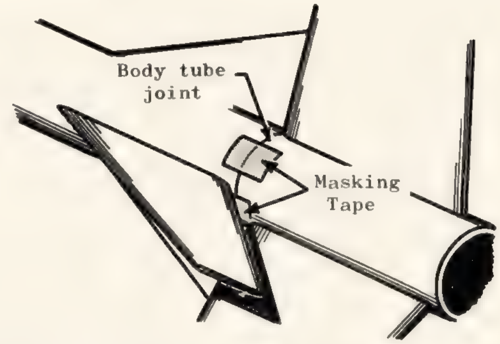


Fig. 7C



Normal procedures call for taping the engines together with cellophane tape before mounting in the rocket. By doing this a better coupling is achieved. Figure 8 illustrates a slightly different method, recommended for use with Series I and Series III boosters only. Applying tape to the outside of the rocket is easier than taping the engines, but is also poor aerodynamic practice.

Fig. 8



With any coupling system, certain rules must be carefully followed. Engines must be held in their respective stages securely. Engine blocks must be strongly glued. Engines may be secured in their body tubes by (1) wrapping tape around the middle of the engine until it makes a very tight friction fit in the body as in fig. 9A, (2) taping the end of the engine to the engine holder tube as in fig. 9B, or (3) by a combination of wrapping the engine with tape and properly positioning engine blocks as in fig. 9C.

Fig. 9A

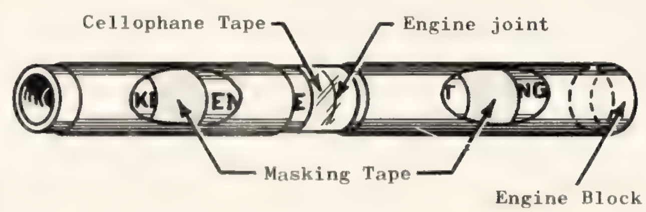


Fig. 9B

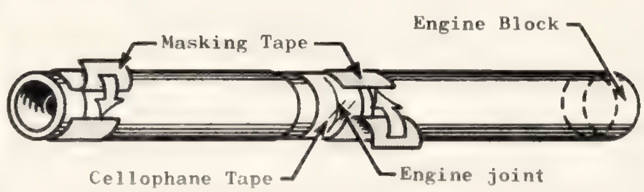
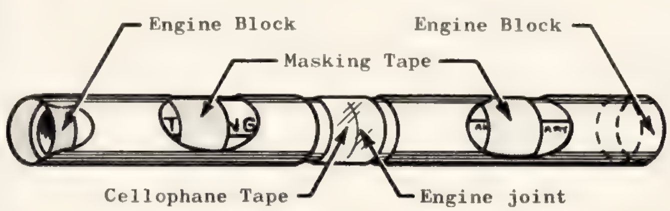


Fig. 9C



When the forward wall of propellant in the booster ruptures and hot gases blow forward, the joint between the engines is pressurized. If the rocket has been constructed with proper care and the engines mounted carefully, the tape that holds the stages together will break, allowing the stages to separate, but not until the upper stage has ignited. If proper care is not exercised, almost anything can happen.

STABILITY

Multi-stage rockets, like single stage rockets, are stabilized by air currents acting against the fins (see technical report TR-1). Since two or more engines are mounted near the rear of the rocket, it has a tendency to become tail-heavy. To compensate for this rearward movement of the center of gravity, extra large fins must be used on the booster or lower stages. As a general rule the lower set of fins on a two stage rocket should have two to three times the area of the upper set. Each additional stage then requires even greater fin area.

When checking a multi-stage design for stability, test first the upper stage alone, then add the next lower stage and test, and so on. In this manner the builder can be sure that his rocket will be stable in each step of its flight, and he will also be able to locate any stage which does not have sufficient fin area. Always check for stability with engines in place.

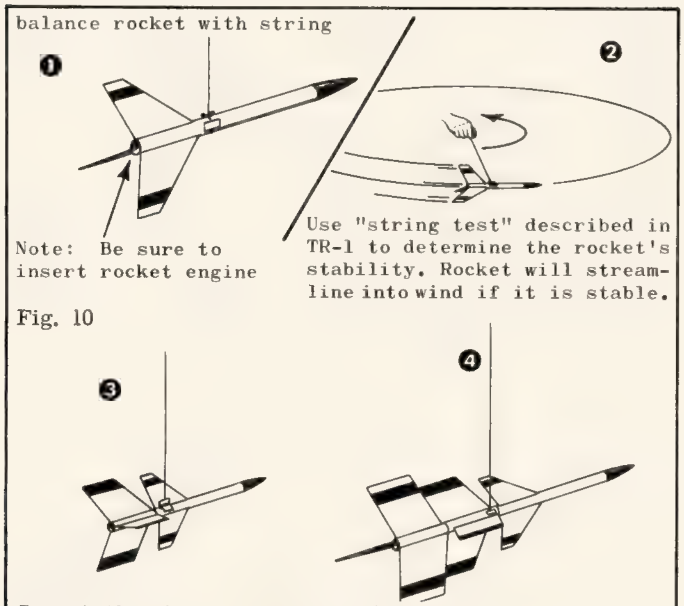


Fig. 10

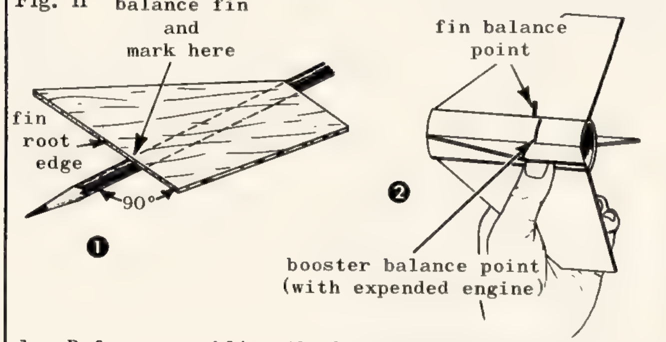
Repeat the above proceedure with each additional booster section. Be sure to insert a rocket engine in each stage.

To obtain the maximum stability from the fin area, care should be taken in construction to create an aerodynamically "clean" shape. The transitions between stages should be as smooth as possible to prevent interrupting the air flow and causing turbulence.

BOOSTER RECOVERY

Most lower stages are designed so that they are unstable after separation. This is because the booster alone is "nose-light," since its center of gravity is fairly close to the stage's rear. The booster should be built so that the center of the area of the fin (its balance point) matches or is up to 1/4" ahead of the booster's balance point with an expended engine casing in place. Thus boosters will require no parachute or streamer, but will normally tumble, flutter or glide back to the ground. If the booster is to be used again, it should be painted an especially bright color, as it does not have a parachute or streamer to aid in spotting it once it is on the ground.

Fig. 11



1. Before assembling the booster, balance one of the fins. Mark the balance point at the fin's root edge.
2. Balance the assembled booster with an <u>expended</u> engine casing in place. The fin balance point must either match or be slightly forward of the booster balance point.

TYPES OF ENGINES

Lower and intermediate stages always use engines which have no delay and tracking charge, and no parachute ejection charge. There is no delay so that the next stage will receive the maximum velocity from its booster. The engines which are suitable are those which have designations ending in zero, such as the A.8-0, B.8-0. 1/4A.8-0S, and B 3-0.

The selection of booster engines will depend on several factors, including the rocket's stability and weight, launch rod length, and weather conditions. Generally heavy rockets and rockets with large fin area should use 1/4A, 1/2A, or B 3 booster engines unless there is <u>no</u> wind blowing. Experience has shown that even a gentle breeze is enough to make these models weather-cock severely, resulting in a loss of altitude and a long chase after the rocket. This is especially so when engines other than those mentioned are used.

In the upper stage an engine with a delay and tracking charge and parachute ejection charge is used. As a general rule the longest possible delay should be used, as multi-staging imparts considerably more velocity to the final stage, and the rocket must have an opportunity to lose this velocity before the parachute is ejected. Greater altitude will be obtained and damage to the recovery system avoided in this manner. Engines suitable for upper stage use are those with long delays such as the B.8-6, A.8-4, B 3-5, etc.

MULTI-STAGE -- BUILDING AND FLYING

Before attempting to build a multi-stage rocket, the rocketeer should build and fly several single stage rockets to familiarize himself with the principles involved. The reliability of a two stage rocket is always less than a single stage rocket, and as more stages are added the reliability drops even farther. Hence more building and flying skill is required as the rockets become more complex.

Fins must be securely glued on multi-stage models, and especially on booster stages since considerable pressure is applied to the fins at stage separation. It is usually a good idea to put launching lugs on both the upper and lower stages of a multi-stage vehicle. Special attention to other details of rocket construction, including attachment of shock cords, nose cone fit, and alignment of fins is also quite important.

When flying multi-stage rockets extra caution should be taken to select a field that is free of dried weeds, grass, or other highly combustable materials. The field should be at least as wide and as long as the maximum altitude the rocket is expected to reach. There should be no persons in the area who are not observing the rocket flight.

Multi-stage rockets should be flown only in reasonably calm weather, as they have an extreme tendency to weathercock. When the rocket is placed on the launcher, care should be taken to assure that the alignment of the stages is not disturbed. Observers should be assigned to follow each individual stage to prevent the loss of part of the rocket.

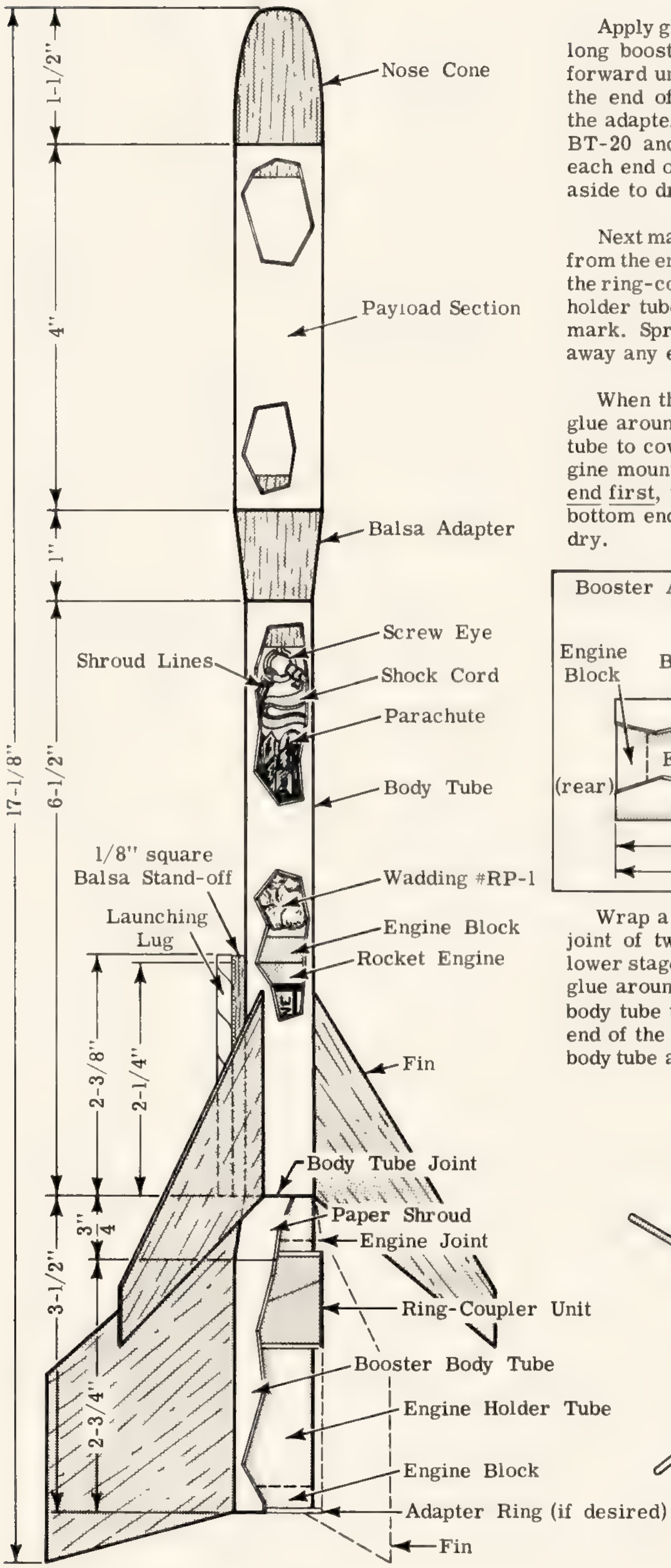
General safety precautions such as adequate recovery systems, not launching when planes are overhead, and others which are normally taken with single stage rockets should also be taken with multi-stage rockets. Attention to safety rules makes rocketry activities considerably more enjoyable and educational.

Estes Industries Rocket Plan No. 20

MINI-X

2-Stage Payload Rocket

Published as a service to its customers by Estes Industries, Inc., Box 227, Penrose, Colorado.

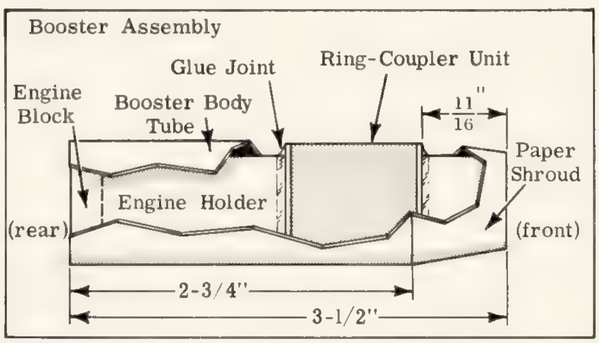


Assembly Instructions

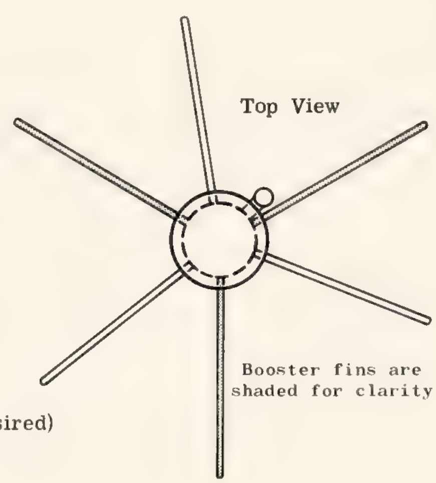
Apply glue to the last 1/4" of the inside of the 3-1/2" long booster tube. Insert an engine block and push it forward until the end of the engine block is even with the end of the tube. Select the two 20-50 rings from the adapter ring set (they should fit tightly around a BT-20 and tightly inside a BT-50). Glue one ring to each end of the JT-50C coupler. Set this assembly aside to dry.

Next mark the 3-1/2" long engine holder tube 11/16" from the end that does not have the engine block. When the ring-coupler unit has dried slide it onto the engine holder tube. The front ring should be exactly on the mark. Spread glue around both ring-tube joints. Wipe away any excess glue with your finger.

When the engine mount has dried completely smear glue around the inside of the 2-3/4" long booster body tube to cover an area 1" from one end. Insert the engine mount unit into this end of the body, engine block end first, until the engine block end is even with the bottom end of the booster body tube. Set this aside to dry.



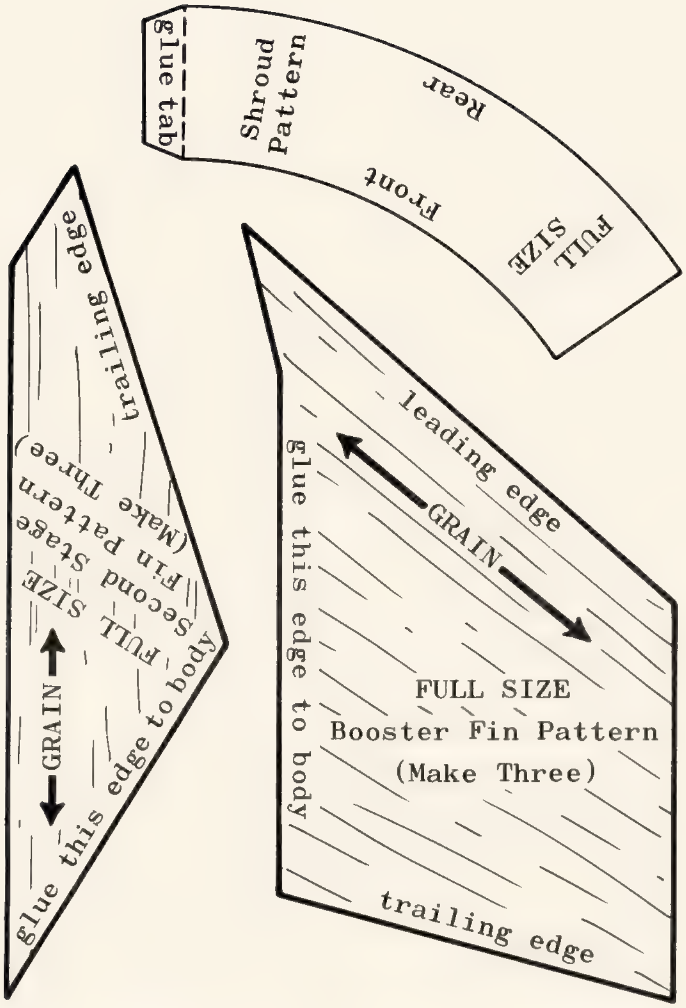
Wrap a layer of cellophane tape tightly around the joint of two rocket engines and slide them into the lower stage. Using your little finger or a brush, smear glue around the inside of the 6-1/2" long upper stage body tube to cover an area approximately 2" from one end of the body tube. Insert an engine block into the body tube and push it into place with the taped engines



Booster fins are shaded for clarity

Parts List

1	Nose Cone	#BNC-50J
1	Body Tube	#BT-50S
1	Balsa Adapter	#TA-2050A
1	Screw Eye	#SE-1
1	Shock Cord	#SC-1
1	Parachute	#PK-12
1	Body Tube	#BT-20D
2	Engine Blocks	#EB-20A
1	Launching Lug	#LL-1B
1	Body Tube	#BT-50J
1	Body Tube	#BT-20G
1	Stage Coupler	#JT-50C
1	Adapter Ring Set	#TA-1
	Balsa Fin Stock	#BFS-20

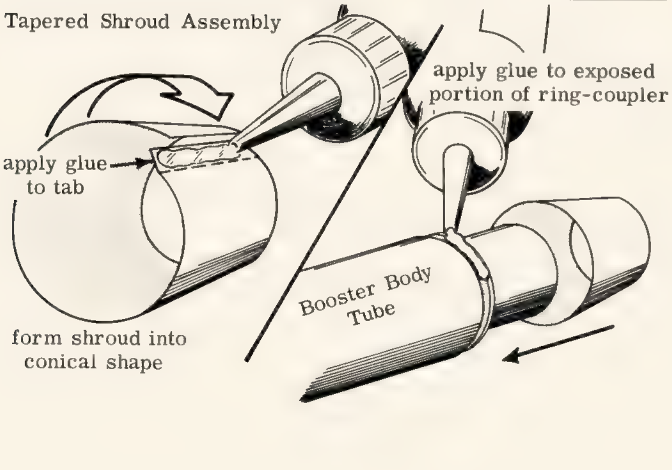


Trace fin patterns onto a separate sheet to preserve plans.

and the lower stage. Remove the engines immediately. (Another method of positioning the engine block is to mark an empty engine casing 2-1/4" from one end. Spread glue around the inside of the 6-1/2" body tube about 2" from one end. Insert an engine block and push it forward into the body tube with the engine casing until the mark on the casing is exactly even with the end of the body tube--and the engine block is 2-1/4" from the end of the body. Remove the engine casing immediately.)

Carefully trace the shroud pattern onto index paper or the heavy paper supplied in the adapter ring set. Cut out the shroud and form it to a conical shape. Apply glue to the tab and hold it in place with the joint exactly covering the tab area. When the glue has set slip the shroud onto the engine holder tube. Spread glue around the exposed part of the ring-coupler unit and slide the shroud up tightly against the booster body tube. Wipe away any excess glue.

Tapered Shroud Assembly



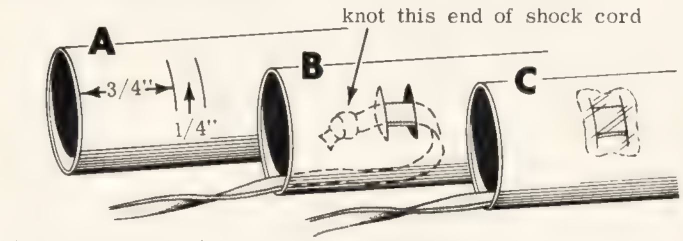
Glue the large end of the balsa adapter to one end of the payload section tube. The nose cone should fit tightly in the other end. If it is too loose wrap its shoulder with tape to increase the diameter.

Cut out three booster fins and glue them to the booster body tube. Match the grain on the balsa with the grain direction indicated on the fin pattern. Align each fin by sighting along the body and adjusting it until the fin is parallel to the body and projects straight away from it. When the glue has dried run a fillet of glue along each fin-body joint. Repeat this procedure with the three second stage fins.

Glue the launching lug to a 2-3/8" long piece of 1/8" square balsa. Glue the balsa to the second stage midway between two fins.

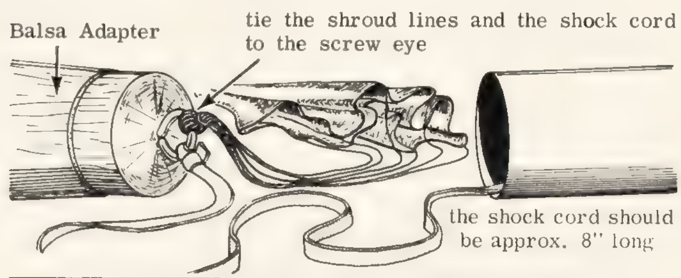
Attach the shock cord and recovery system as shown in the illustrations below.

Shock Cord Installation



A. Cut two slits 1/4" apart in the forward end of the upper stage body tube.
B. Press in the section between the slits and thread the shock cord through the opening.
C. Push the caved-in portion outward and seal with glue.

Attaching Recovery System



Paint the model and apply decals. Tape the upper and lower stage engines together with cellophane tape and secure tightly in the rocket as described in TR-2 (published in the Feb. '64 issue of the Model Rocket News). These procedures must be followed or the rocket will not fly correctly.

Recommended Engines

Upper Stage		Lower Stage	
1/4A. 8-4	1/2A. 8-4	1/4A. 8-0	1/2A. 8-0
A. 8-4	B. 8-6	A. 8-0	B. 8-0
		B. 3-0	C. 8-0

(Use 1/4A. engines for first flights.)

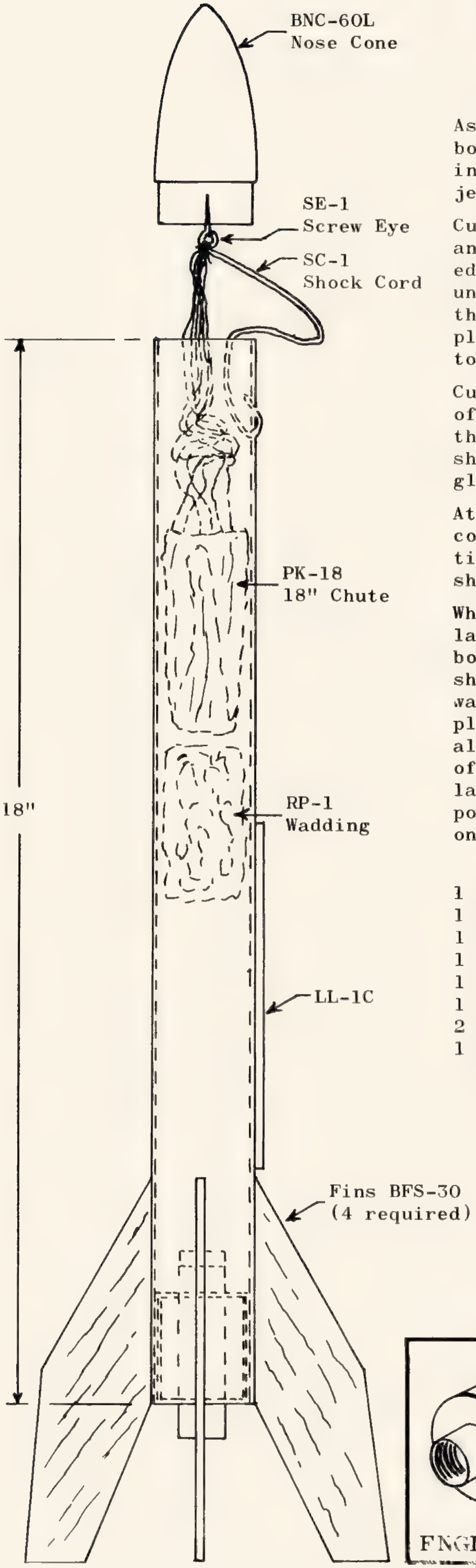
Use Series I and Series II engines only.

Suggested Engine Combinations

	1st Stage	2nd Stage
Medium Altitude with light payload	1/4A. 8-0	1/4A. 8-4
Medium Altitude with 1/2 oz. payload	1/2A. 8-0	1/2A. 8-4
Medium Altitude with 1 oz. payload	A. 8-0	A. 8-4
High Altitude with light payload	B. 8-0	B. 8-6
Extra High Altitude with light payload	C. 8-0	B. 8-6
High Altitude with 1 oz. payload	B. 3-0	B. 8-6

Other combinations of engines may be used to obtain desired flight performance.

(Maximum recommended payload weight is 1 oz.)



BIG BERTHA

ESTES INDUSTRIES ROCKET PLAN NO. 13

Assemble the engine mount and glue it in place in the rocket body. Be sure the engine block end of the mount is inserted into the tube first, with the clear end of the mount projecting out of the end of the rocket as shown.

Cut out the fins. Sand the sides of the fins until smooth and sand all edges <u>except</u> the edge that is attached to the body until smooth and round. Mark the tube and glue the fins in place. Glue the launching lug to the body tube.

Cut two slits in the forward end of the body, 1" and 1-1/4" from the front. Pass one end of the shock cord through the slits and glue in place.

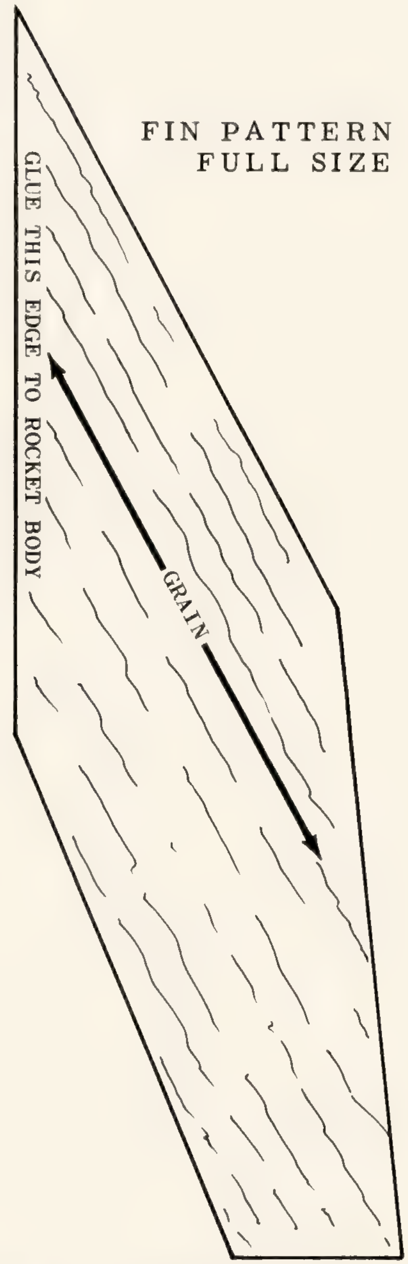
Attach the screw eye to the nose cone. Assemble the parachute and tie it and the free end of the shock cord to the screw eye.

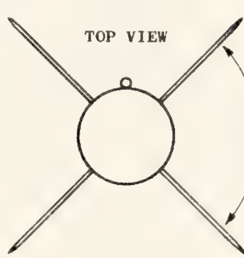
When flying Big Bertha pack a large piece of wadding into the body, then pack the parachute and shroud lines in loosely over the wadding. Secure the engine in place by wrapping tape tightly all the way around the outside of the engine holder tube, overlapping from the tube to the exposed part of the engine. Use only B.8-2 and B.8-4 engines.

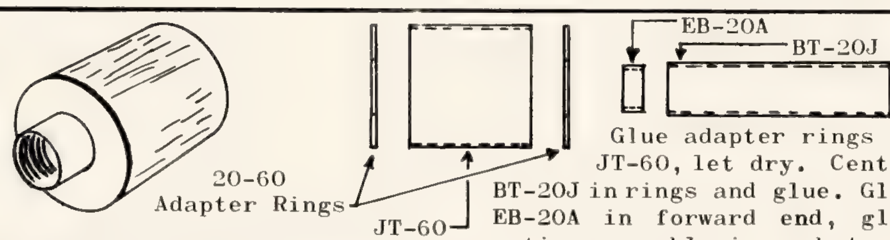
PARTS LIST

1	Nose Cone	#BNC-60L
1	Body Tube	#BT-60
1	Screw Eye	#SE-1
1	Shock Cord	#SC-1
1	Parachute	#PK-18
1	Launching Lug	#LL-1C
2	Sheets Balsa Stock	#BFS-30
1	Engine Mount Kit	#EH-2060
	Flameproof Wadding	#RP-1

FIN PATTERN
FULL SIZE







Glue adapter rings to JT-60, let dry. Center BT-20J in rings and glue. Glue EB-20A in forward end, glue entire assembly in rocket.

ENGINE HOLDER ASSEMBLY

Estes Industries Technical Report TR-3

ALTITUDE TRACKING

Single Station Tracking

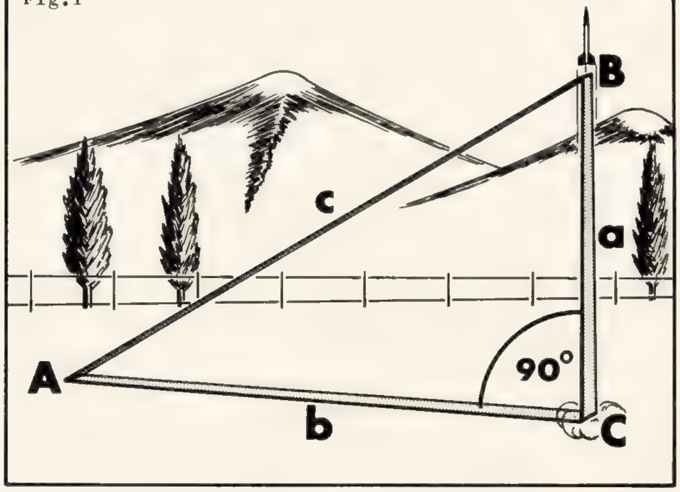
Every Rocketeer asks the question: "How high did it go?" However, previously few model rocketeers had the facilities to determine altitudes with any reasonable degree of accuracy. Some have attempted to find the altitude achieved by their rockets by the use of a stop watch, but this method is so highly inaccurate that the computed altitude may fall anywhere within 200% of the actual altitude. Several years of experience among model rocketeers have proven that optical systems are the only practical means for finding altitudes with any reasonable degree of accuracy.

The use of an optical tracking system requires the use of mathematics. The particular field of mathematics which is used the most in altitude computation is trigonometry. While this field is normally considered an advanced high school subject, any rocketeer can master its basics and apply them to his rocketry activities. If the rocketeer masters a few simple processes, he is ready to solve almost any problem in altitude computation.

One of the first principles of trigonometry is that all of the angles and sides of any triangle can be found if any three of its parts, <u>including</u> one side are known. Now every triangle has six parts: three angles and three sides. So if we know two angles and one side, we can find the other angle and the other two sides.

In determining the height of a rocket we collect two types of data: Distances and angles. This data is used to create a triangle which is a model of the lines which would join the tracker and the rocket, the rocket and a point directly below it on the ground, and the point on the ground and the tracker.

Fig.1



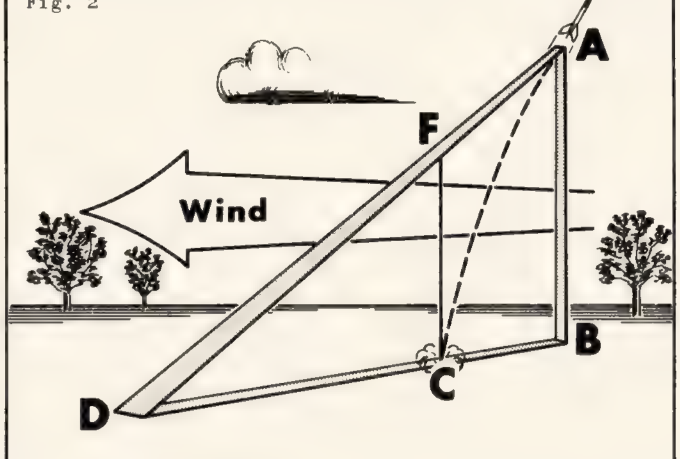
In the diagram above, point A represents the tracking station, B the rocket at its maximum altitude, and C a point on the ground directly below the rocket. The angle formed by the lines at C is then a right angle or 90°. Since there are 180° in the angles of a triangle, if we know angle A, we can find angle B, since $B = 180° - (A + C)$, or $B = 90° - A$. (In trigonometry, a capital letter represents an angle, a small letter represents a side. The small letter "a" will always be used to represent the side opposite angle A, "b" the side opposite B, etc. Two capital letters together represent a distance. Thus BC represents the distance from angle B to angle C, or side "a."

At the firing range, A is found by the tracker when he locks his scope at the rocket's peak altitude. If we now know the distance from A to C, or side b of the triangle, we can find side c and side a. Side a is the one in which we are interested: It is the height of the rocket. This of course assumes that angle C is a right angle.

Now if we only use one tracker, we have the problem of knowing only one angle and one side. This is not enough information to solve the other sides of the triangle. However, we can guess at one of the unknown angles, and obtain a good approximation of the height achieved by the rocket.

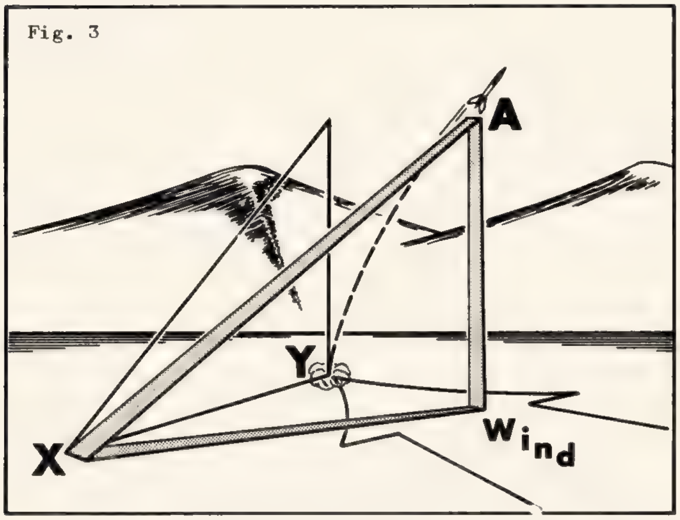
If only one elevation tracker is used, it is a good idea to station it at a right angle to the wind flow. For example, if the wind is blowing to the west, the tracker should be either north or south of the launcher. In this way we will keep the angle at C as close to a right angle as possible. By experimenting with a protractor and a straight edge, the rocketeer can demonstrate why the error would be less if the tracker is on a line at a right angle to the flow of the wind.

Fig. 2



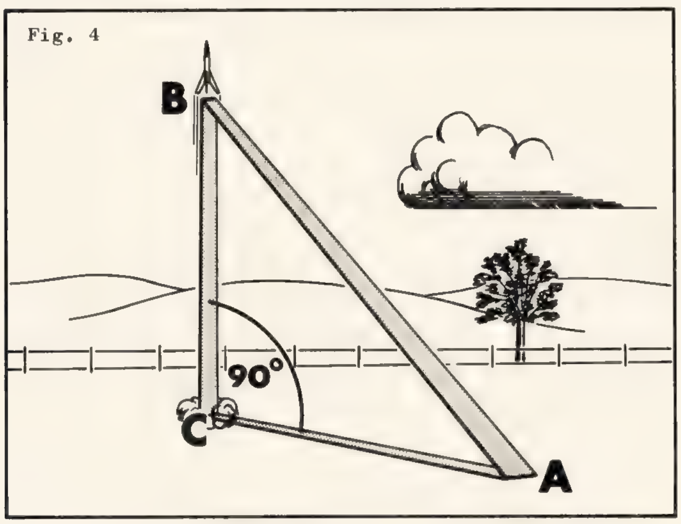
In the diagram above, the wind is blowing from B to D. The rocket is launched at point C, weathercocks into the wind, follows approximately line CA, and at its maximum altitude is at point A. If the tracker is downwind from the launcher, he will see the rocket at point F, and compute the altitude as the distance from C to F. So his computed altitudes will be considerably lower than the true altitudes. On the other hand, if the rocket drifts toward him, his computed altitude will be considerably higher than the true altitude.

However, if the tracker is at point X in figure 3 and the launcher at Y, then the rocket will appear to be at point A as in figure 1, although the distance from the tracker to point A will be slightly greater than the baseline used in computing the altitude, the error will not be nearly as great. Also, the small additional distance will serve to make altitude readings more conservative, as the baseline will be increased.



So by observing the proper relation between wind direction and the position of the tracker, we can generally determine with 90% or better accuracy the altitude the rocket reaches from data given by only one elevation tracker. Of course, the closer the rocket flight is to the vertical, the more accurate will be the figures obtained. Thus on a calm day with a good model, we can approach almost perfect accuracy.

The method used to determine altitude with one tracker is outlined below. Bear in mind that this system assumes that the flight will be almost vertical, if not completely vertical. The rocketeer would do well to master this system before going on to more complex systems, as this method is used as a part of the more involved procedures.



If we assume that the rocket flight is vertical, we can call angle C a right angle (90°). In that case, B is equal to 90° - A (the sum of the angles in a triangle is 180°, half of this or 90° is taken by angle C). Then to find the distance from C to B or the height the rocket reached we take the <u>tangent of angle A</u> (abbreviated tan) <u>times the distance from the tracker to the launcher</u> (side AC of the triangle). For example, if the distance from the tracker to the launcher (baseline) is 250 feet and the angle observed by the tracker at the rocket's maximum height is 62°, we will look in the table of trigonometric functions and find the tangent of 62°. The tangent in this case is 1.88, so we multiply 1.88 times 250 to find our altitude, which is 470'. Altitudes for model rockets are normally rounded off to the nearest ten feet. If the calculated altitude had been 332 feet we would have rounded it off to 330 feet.

Why do we use the tangent to determine altitude? The tangent of an angle is the ratio of the opposite side to the adjacent side, or in other words, the opposite side divided by the adjacent side. In this case, the adjacent side is the distance from the tracker to the launcher, and the opposite side is the distance from the launcher to the rocket's maximum altitude.

Kind souls of many years ago were nice enough to determine the tangents for all angles of right triangles, so we have a table which lists them. Since the tangent of the angle equals the opposite side divided by the adjacent side, or in the case of our first example, 470 divided by 250, by multiplying the quotient times the divisor we find the dividend. In our case, the quotient or tangent is 1.88, the divisor 250, and the dividend 470.

Summary

(1) In single station elevation tracking, we make sure that the line from the tracking station to the launcher is 90° from the direction of wind flow.

(2) The angle of flight is assumed to be vertical.

(3) The tracking scope is locked at the rocket's maximum altitude, the angle read, and the tangent of the angle found.

(4) The tangent is multiplied times the distance from the tracker to the launcher, giving the rocket's altitude.

Two Station Tracking

A higher degree of accuracy is possible when two elevation tracking stations are employed. In such a case, we will have triangles with 2 angles and one side given, enabling us to determine the other parts of the triangle without guesswork.

When using two trackers without azimuth readings the tracking stations are set up on opposite sides of the launcher. Preferably, to obtain the greatest accuracy, the stations should be <u>in line with the wind</u>, unlike the system used in single station tracking. Thus, if the wind is blowing to the south, one station will be north and the other south of the launch area.

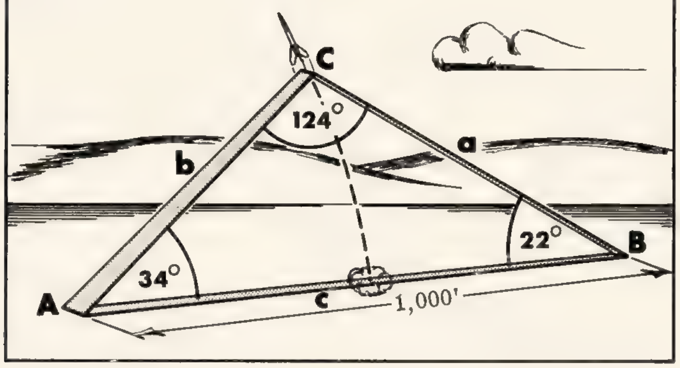
The distance between the two trackers is not critical. One might be 100 feet from the launcher and the other 500 feet away. However, for the greatest ease in data reduction, the distances should be equal. For the greatest accuracy, they should be as far apart as possible. A general rule is that the distance from the stations to the launcher should be equal to or greater than the maximum altitude the rocket is expected to achieve.

Some provision should be made to insure that the trackers lock their instruments at the same time. This is one of the greatest problems with any system using more than one station: The one tracker may lock his scope when the rocket appears to him to have ceased rising while the other tracker is still following the rocket. If a phone system is used, one of the trackers or a third party should call "mark," and the trackers should lock their scopes immediately. In the system described here this is especially important, as the elevation readings from the two trackers must be taken at the same point or the altitude computed will be somewhat incorrect.

In this more accurate system we will work with sines instead of tangents. To determine altitude, then, we will first have to find the unknown sides of the triangle, as we have no right angles to work with.

For example, stations A and B are located on a 1000' baseline with the launcher between them. Station A calls in an elevation of 34°, and station B calls in an elevation of 22°. The total of these two angles is 56°, so angle C, located at the peak of the rocket's flight, is equal to 180° - 56°, or 124 degrees. We now have 3 angles and one side to work with. Our first step will be to list the angles and their sines. Since the sine

Fig. 5

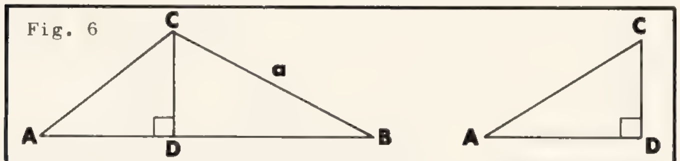


of any angle greater than 90° is equal to the sine of the supplement of the angle, the sine of 124° is equal to the sine of 180° - 124°, or 56°.

Angle A = 34°	Sine A = .5592
Angle B = 22°	Sine B = .3746
Angle C = 124°	Sine C = .8290

The law of sines states that $\frac{c}{\text{SinC}} = \frac{b}{\text{SinB}} = \frac{a}{\text{SinA}}$
c = 1000', sinC = .8290 Therefore, $\frac{1000}{.8290} = \frac{b}{.3746} = \frac{a}{.5592}$ Pulling out the slide rule, we determine that $\frac{1000}{.8290} = 1205$. So we have a dividend, divisor, and quotient. In solving for side b, our dividend is b, our divisor .3746, and our quotient 1205. To find the dividend we multiply the divisor times the quotient. Now .3746 times 1205 = b, and pulling out the slide rule again, we find that b = 451. The same process is repeated to find side a: $1205 = \frac{a}{.5592}$, a = 1205 x .5592, a = 674'. So we now have the three sides of the triangle.

Fig. 6



The altitude of the rocket is then the distance from C to D in the diagram above. The angle formed by the meeting of lines AB and CD is a right angle. Since the sine of an angle in a right triangle is the relation of the opposite side to the hypotenuse, and since we wish to determine the value of the opposite side, we find that the sine of A (34°) is .5592. Hence $.5592 = \frac{a}{451}$, since $\text{SinA} = \frac{\text{opposite side}}{\text{hypotenuse}}$. .5592 x 451 = 252, hence CD = 252', and we now know the altitude reached by the rocket was 252'.

Fortunately, our computations to determine the altitude of the rocket can be simplified. To find the altitude we need only determine one of the unknown sides of the original triangle. So if we find the distance BC (side a) on the triangle, we can multiply it times the sine of B to find the height CD.

So $\frac{c}{\text{SinC}} = \frac{a}{\text{SinA}}$. Since we have found $\frac{c}{\text{SinC}}$ equal to 1205 when C = 124°, $\frac{a}{\text{SinA}} = 1205$. Then 1205 x SinA= side a = 674'. Now we have the one needed side of the triangle, so we can solve for distance CD in the right triangle BCD. The sine on an angle is equal to its opposite side divided by the hypotenuse, so we take the sine of B, which is .3746, times the hypotenuse, or 674' to find the opposite side CD. Thus .3746 x 674 = 252'.

The complete series of computations then would be $\frac{c}{\text{SinC}}$ x SinA = a, and a x SinB = CD. However, if we can combine the formulas to make one formula, we can speed up our work considerably. Now $\frac{c}{\text{SinC}}$ x SinA = A, so we can substitute the expression ($\frac{c}{\text{SinC}}$ x SinA) for a in the formula a x SinB = CD. Our formula then becomes $\frac{c}{\text{SinC}}$ x SinA x SinB = CD. One of the basic rules of algebra tells us that if the dividend is multiplied by a number and the result divided by the divisor, the result is the same as if the division were carried out first and the quotient multiplied by the number. For example, $\frac{10 \times 4}{5} = 8$, and $\frac{10}{5} \times 4 = 8$.

So we can change the expression $\frac{c}{\text{SinC}}$ x SinA x SinB = CD to read $\frac{c \times \text{SinA} \times \text{SinB}}{\text{SinC}}$ = CD. So by performing two multiplications and one division, we can find the altitude of the rocket. The division of SinC into the expression (c x SinA x SinB) can occur at any point, as $\frac{c \times \text{SinA}}{\text{SinC}}$ x SinB = CD, and c x $\frac{\text{SinA} \times \text{SinB}}{\text{SinC}}$ = CD also. This last form of the equation will give the same result as the first, and actually involves the same steps, but is generally easier to use.

Summary

(1) In two station tracking without the use of azimuth readings we station the trackers on a base line approximately equal to twice the altitude the rocket is expected to reach.

(2) The trackers are located <u>in line with the wind</u>.

(3) The scopes are locked at the rocket's maximum altitude, the angles read, and the sines of the angles found.

(4) The altitude is computed by the formula height = $\frac{c \times \text{SinA} \times \text{SinB}}{\text{SinC}}$, when A and B are the angles read by the trackers, c is the baseline distance, and C is the third angle formed by the meeting of the lines of sight of the two trackers.

Sines and Tangents

∠	sin	tan	∠	sin	tan	∠	sin	tan
1	.02	.02	28	.47	.53	54	.81	1.38
2	.03	.03	29	.48	.55	55	.82	1.43
3	.05	.05	30	.50	.58	56	.83	1.48
4	.07	.07	31	.52	.60	57	.84	1.54
5	.09	.09	32	.53	.62	58	.85	1.60
6	.10	.11	33	.54	.65	59	.86	1.66
7	.12	.12	34	.56	.67	60	.87	1.73
8	.14	.14	35	.57	.70	61	.87	1.80
9	.16	.16	36	.59	.73	62	.88	1.88
10	.17	.18	37	.60	.75	63	.89	1.96
11	.19	.19	38	.62	.78	64	.90	2.05
12	.21	.21	39	.63	.81	65	.91	2.14
13	.22	.23	40	.64	.84	66	.91	2.25
14	.24	.25	41	.66	.87	67	.92	2.36
15	.26	.27	42	.67	.90	68	.93	2.48
16	.28	.29	43	.68	.93	69	.93	2.61
17	.29	.31	44	.69	.97	70	.94	2.75
18	.31	.32	45	.71	1.00	71	.95	2.90
19	.33	.34	46	.72	1.04	72	.95	3.08
20	.34	.36	47	.73	1.07	73	.96	3.27
21	.36	.38	48	.74	1.11	74	.96	3.49
22	.37	.40	49	.75	1.15	75	.97	3.73
23	.39	.42	50	.77	1.19	76	.97	4.01
24	.41	.45	51	.78	1.23	77	.97	4.33
25	.42	.47	52	.79	1.28	78	.98	4.70
26	.44	.49	53	.80	1.33	79	.98	5.14
27	.45	.51				80	.98	5.67

For angles of 81° through 89° the sine is .99, the sine of 90° is 1.00. Tangents over 80° are not given, as no sensible data reduction is possible for angles that great.

Estes Industries Rocket Plan No. 15

SPUTNIK – TOO!

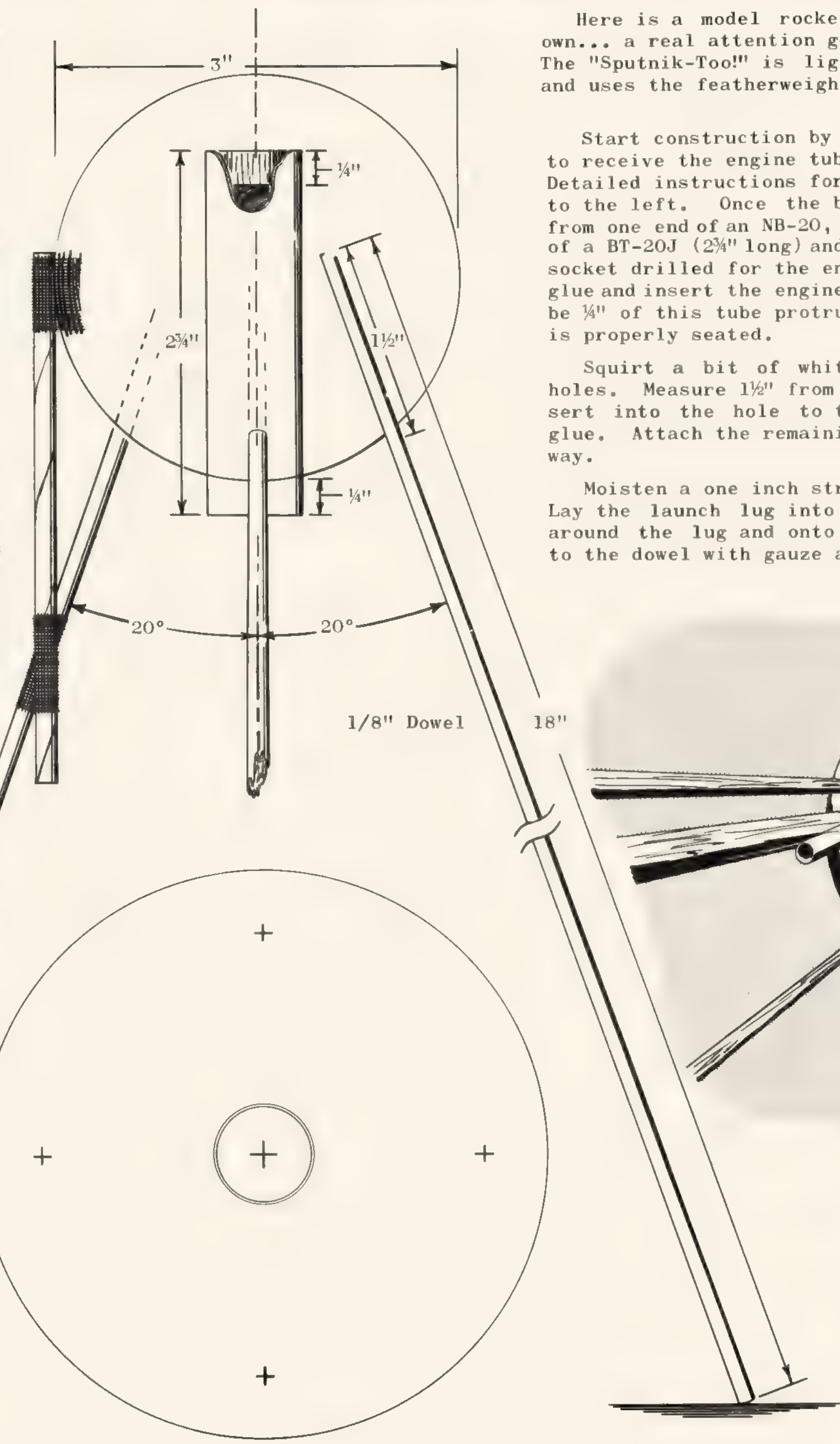
AN ODDBALL...

Published as a service to its customers by Estes Industries, Inc., Box 227, Penrose, Colo.

Cut-a-way shows you where each part fits in and around the styrofoam ball.

Tape the template to the styrofoam ball placing a piece of tape near each of the four dowel positions. This will hold the template firmly as you press a pencil or other pointed tool through the center of each position marker (+) to clearly score the ball surface.

Drill a ¾" hole to 2½" depth, centered on line of thrust. Now drill 1/8" holes at angle that would cause all four dowels to meet at the line of thrust were they to emerge from the front of the ball. DRILL ONLY TO DEPTH OF 1½".

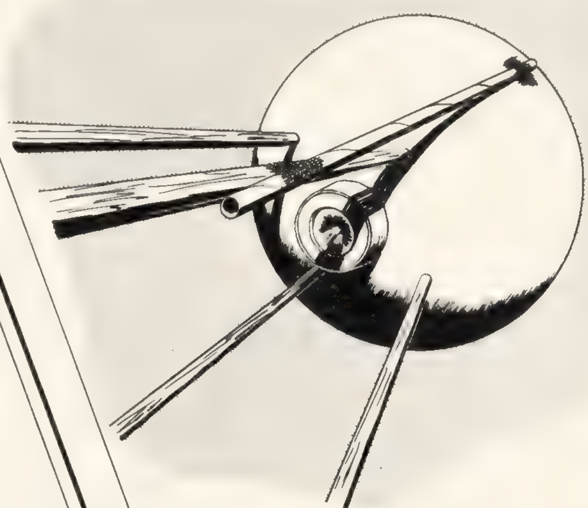


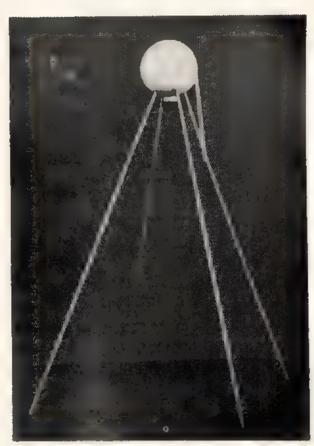
Here is a model rocket with a character all it's own... a real attention getter where ever it appears! The "Sputnik-Too!" is light in weight, easy to build and uses the featherweight recovery principle.

Start construction by preparing the styrofoam ball to receive the engine tube and dowel stabilizers. Detailed instructions for use of the template are seen to the left. Once the ball is ready, cut a ¼" slice from one end of an NB-20, glue this slice into one end of a BT-20J (2¾" long) and stand aside to dry. Smear socket drilled for the engine tube with a film of white glue and insert the engine tube assembly. There should be ¼" of this tube protruding from the ball when tube is properly seated.

Squirt a bit of white glue into one of the 1/8" holes. Measure 1½" from one end of the dowel and insert into the hole to this point. Wipe off excess glue. Attach the remaining three dowels in this same way.

Moisten a one inch strip of gauze with white glue. Lay the launch lug into position and form the gauze around the lug and onto the ball. Secure the other to the dowel with gauze as shown.





1	Styrofoam ball, 3" O.D.	Part #	SB-3
4	Dowel, 18" x 1/8" Dia.	" "	WD-1
1	Body tube 2¾" long	" "	BT-20J
1	Nose block piece	" "	NB-20
1	Launching Lug, 5" long	" "	LL-1C

NOTE: Rather than use the 5" launching lug, you may desire to mount a short lug on the ball and another lug on the dowel. If so, use another dowel to line them up.

Estes Industries

Rocket Plan No. 12

March, 1963

SKY SLASH II

Winning Design

Estes Industries Boost-Glide Contest

by

Larry Renger

About the Designer

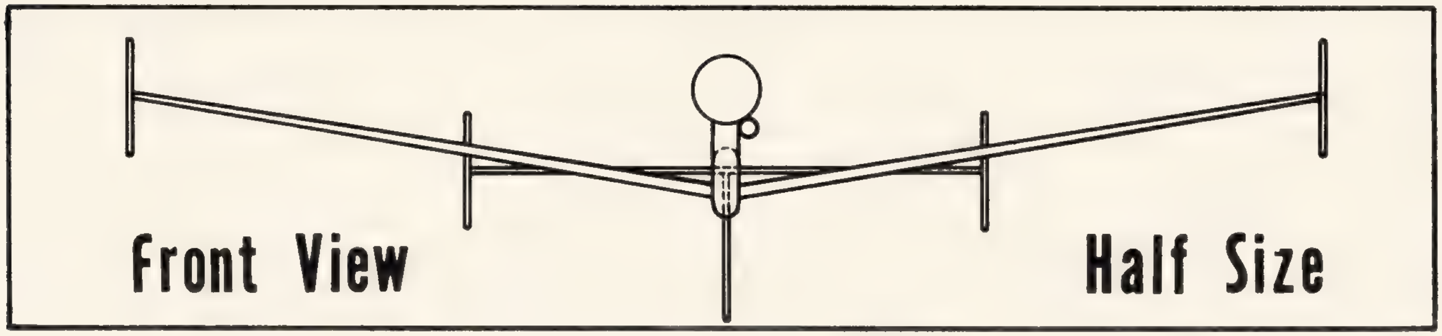
Larry Renger is a Senior in Aeronautical and Astronautical Engineering at Massachusetts Institute of Technology. A serious modeler for over seven years, he also holds three AMA indoor records, and combined his skills in model aeronautics and model rocketry to produce this design.

Parts List

1 Nose Cone BNC-20B
1 Sheet Balsa BFS-80
2 Sheets Balsa BFS-40
2 Sheets Balsa BFS-20
1 Body Tube BT-20
1 Launching Lug LL-1B
1 Nose Cone Weight NCW-1

Equipment Needed

1 Knife or Razor Blade
1 Bottle White Glue
1 Sheet Medium Sandpaper
2 Sheets Extra Fine Sandpaper
1 Pair Scissors
1 18" Straight Edge
1 Coping or Jig Saw



Assembly Instructions

This model is recommended only for the experienced modeler, as care and precision in the building are necessary for satisfactory results. The rocketeer who has previous experience with both boost-gliders and model airplanes is in the best position to build this glider.

Begin construction by tracing the patterns for the balsa parts onto the proper sized balsa sheets. Be sure that the balsa thickness is the same as that indicated on the plan sheet. Cut out the parts, being careful to run the wood grain in the direction required.

Sand the wings to the airfoil shown on the plans, and sand all other parts to achieve a smooth surface. Using a straight edge at least 18 inches long, mark the body for wing, stabilizer, and engine alignment. For this alignment, hold one end of the straight edge so that its edge is at the point on the rear of the body where the top of the stabilizer will come, run the other end of the straight edge to fall on the position for the bottom of the wing, and draw a line here for aligning the wing. Sand the 2 1/4" notch in the bottom of the rear of the body so that the notch's surface will run exactly on the line from the bottom of the wing to the rear of the body. Sand the upper forward part of the body so that the edge to which the engine holder tube is attached will be exactly parallel with the line from the wing to the stabilizer.

Turn the body piece upside-down and prop it in position so the wing attachment line is one inch from the surface of the table and so the line is exactly parallel to the surface of the table. Glue the wings in position, with the flat underside of the wing exactly on the line drawn previously, allowing the wing tips to rest on the table surface. While the glue on the wings is drying, assemble separately the complete tail section. Make sure that all portions of the tail are straight, with the rudder at a 90 degree angle to the stabilizer.

After the glue on both the wings and the tail has dried thoroughly, hold the tail in place against the body, and using the straight edge, check to be sure the wings and tail will fall exactly in line, and be sure that the forward upper surface where the engine holder tube will be attached is exactly parallel to the wing-tail line. Glue the assembled tail in place, checking to be sure that the alignment is still correct. If a wide, circular glide is desired, glue the tail assembly in place so that one tip is 1/8" higher than the other tip. After the glue holding the tail to the body has hardened, check the alignment again, then check to be sure the forward upper surface is still parallel to the wing - tail line. Glue the nose cone in the engine holder tube, glue the engine holder tube to the body, and glue the tip plates in position on the wings.

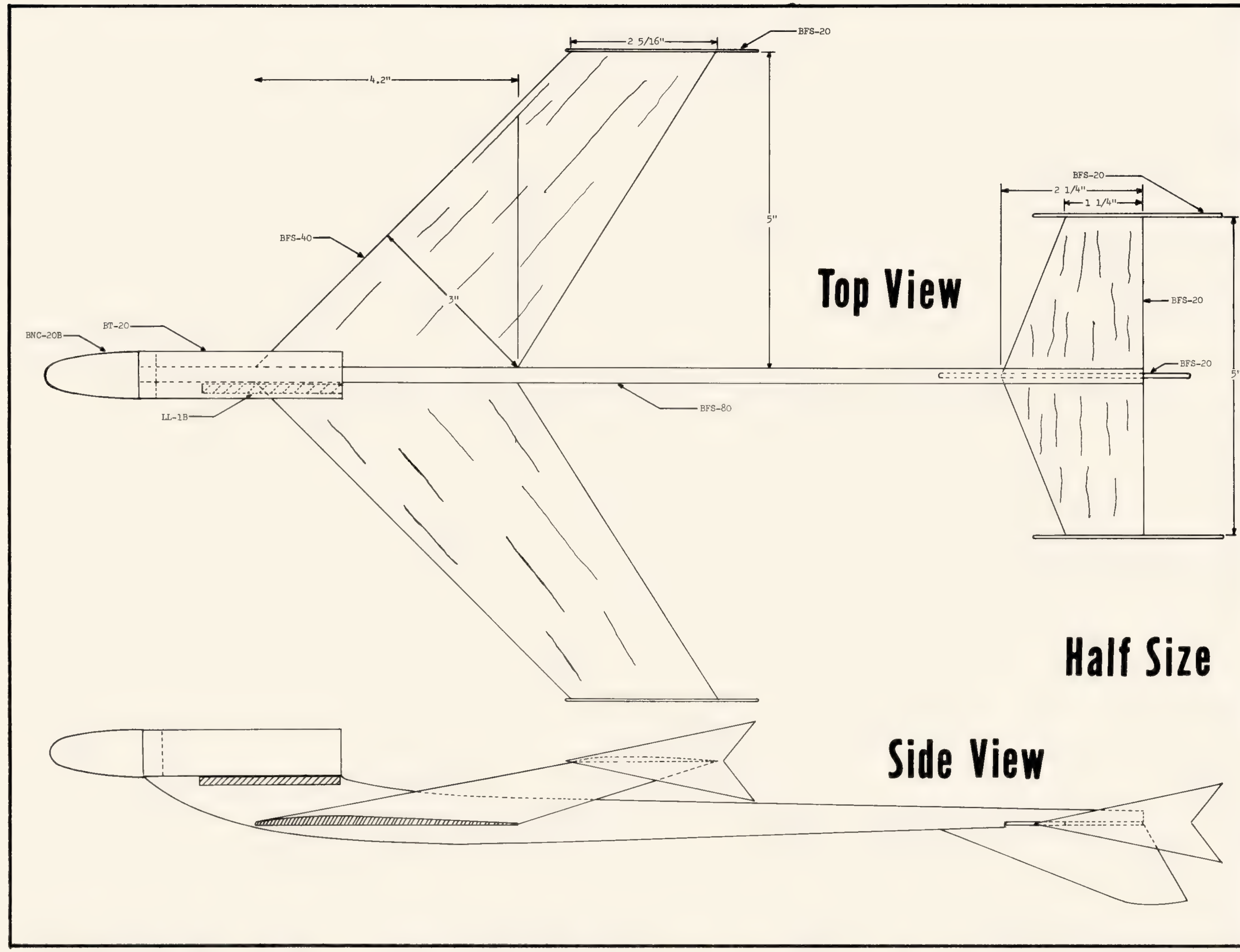
When all these glue joints have hardened, apply a glue fillet to all joints with the exception of the nose cone joint. Apply a light coating of white glue to the upper surface of the body for its entire length to protect the body from the exhaust gases. Glue the launching lug in place. A second fillet layer may be applied to the wing-body joint to give it additional strength.

Punch or cut one 3/16" diameter or several 1/16" diameter ejection pressure relief vent holes in the engine holder tube 1/8" back from the base of the nose cone. To check the positioning of the holes, place an engine casing in the holder tube, mark the casing where the rear of the holder comes, take the casing out, lay the casing against the tube with the mark next to the rear of the tube, mark the tube where the forward end of the casing touches it, and cut the hole 1/8" back of this point.

Before flying the Sky Slash II, balance it for glide by hand launching it and adding small amounts of weight (slivers of nose cone weight NCW-1) to the nose if the rocket stalls, or to the tail if the rocket comes in too fast. When the Sky Slash II is properly balanced, it should travel at least 20 feet forward for every foot of drop when hand launched lightly. Hand launched duration should average over four seconds for a well balanced model, although the maximum for a particular model will vary. The best way to get the best glide is to work on the balancing until the model feels right and appears to glide right, both of which are part of the modeler's skill gained only through practice. Generally the balance point for the glider will be in the region of the rear of the wing-body root joint.

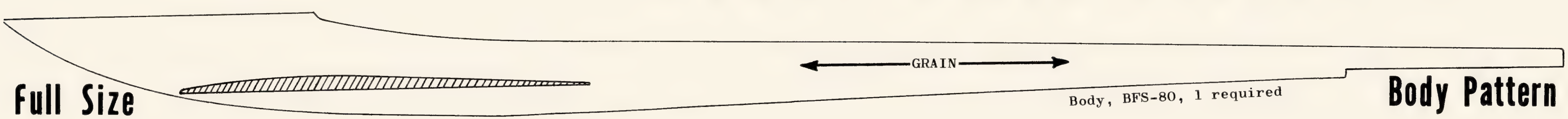
The first flights on the Sky Slash II should be made with 1/4A.8-2 engines if the glider without engine weighs less than 20 grams (3/4 ounce, determined by weighing on a balance; the science department at your school should have one) or with 1/2A.8-2 engines if the rocket is heavier. Individual weights will vary with the amount of sanding, balancing weight, and paint. Generally, the lighter the glider, the longer the flight. For most sport flying, the 1/4A and 1/2A engines are recommended, as the Sky Slash II may well go out of sight on the glide with larger engines. For contest use, the B.8-2 engine is recommended.

If the Sky Slash II fails to rise vertically on its initial flights, the alignment of the various parts should be checked carefully and corrections made if necessary. In addition, if one wing is heavier than the other, the glider may tend to turn in the direction of the heavier wing under power and in glide. If this is the case, the proper amount of weight added near the tip of the light wing will correct this. If there is much difference between the airfoils of the two wings, this may also cause a poor flight. As experience is gained in the use of this design, it will be possible to achieve better vertical flights and longer durations, as much of the performance of this rocket is dependent on the rocketeer's own skill.

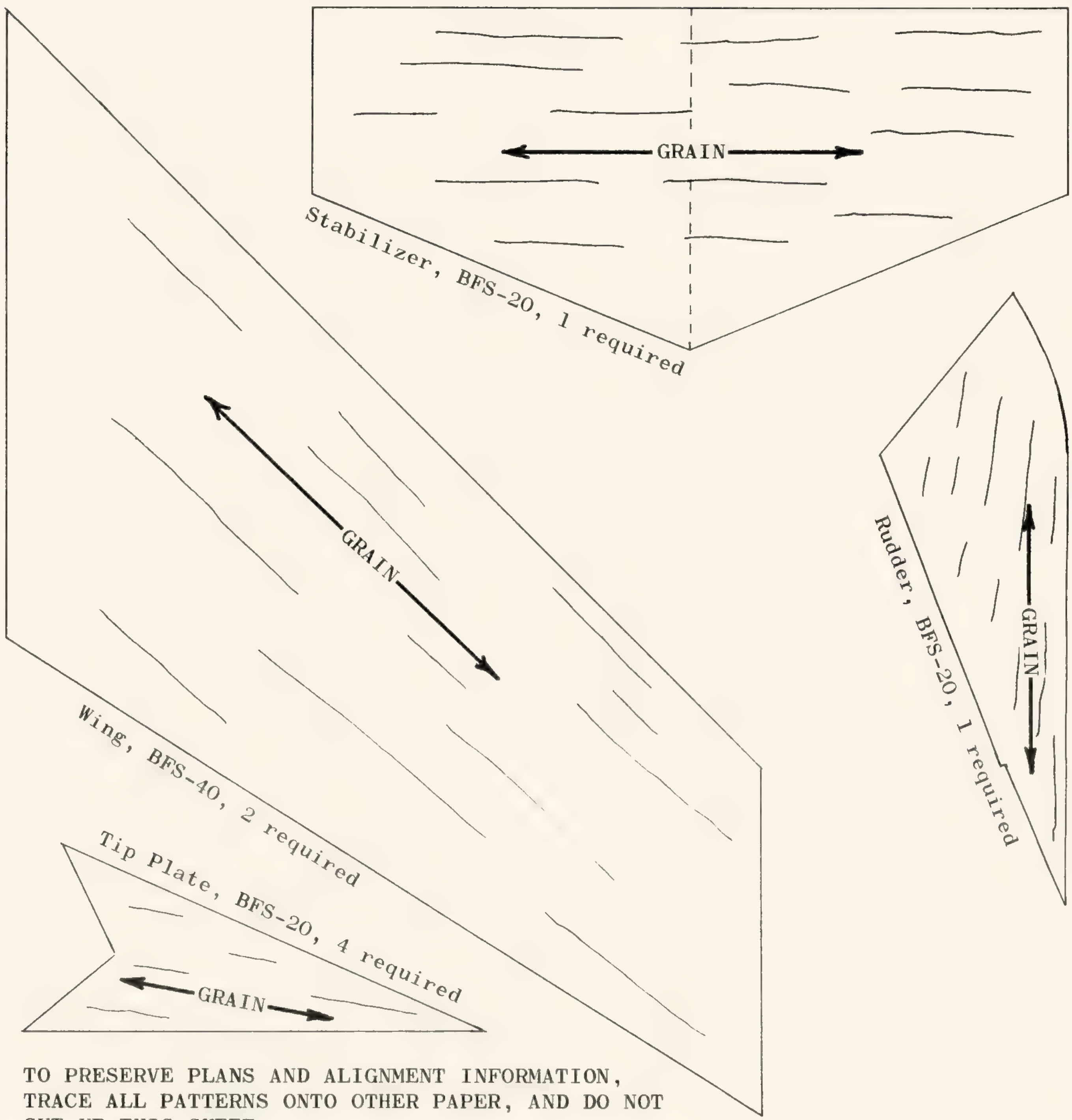


SKY SLASH II

Design by Larry Renger



Full Size Body Pattern



TO PRESERVE PLANS AND ALIGNMENT INFORMATION, TRACE ALL PATTERNS ONTO OTHER PAPER, AND DO NOT CUT UP THIS SHEET.

Launching Information

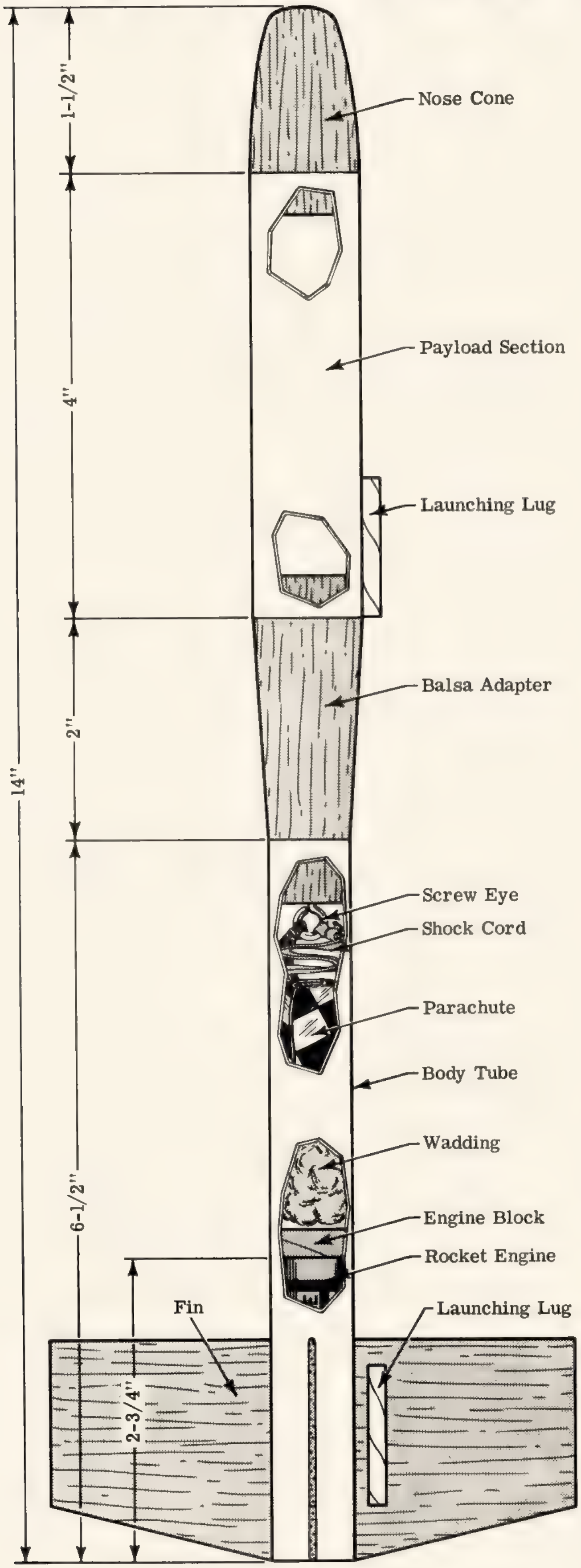
The Sky Slash II is launched vertically using an electric firing system. DO NOT launch the Sky Slash II at any angle greater than 30 degrees from the vertical, as this can result in the destruction of the model. Some launchers will require lengthening the leads to the micro-clips to allow attaching them to the ignitor. This can be done by cutting two 20 inch lengths of #18 wire, attaching micro-clips to one end of each, and gripping the other ends of the wires with the clips already on the launcher. Do not use Jetex wick with the Sky Slash II, as the exposed balsa is especially subject to damage by the flame of the wick.

Estes Industries Rocket Plan No. 19

LOADLIFTER 1-A

Winning Design
Favorite Design Contest

by **Merrell Lane**



Assembly Instructions

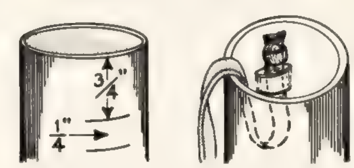
Spread glue around the inside of one end of the 6-1/2" long body tube as far in as you can reach with your little finger. Insert an engine block and push it forward into the body tube with an empty engine casing. Move the block forward until the end of the engine casing is even with the end of the body tube (and the engine block is 2-3/4" from the end of the body). Remove the engine casing immediately.

Cut out four fins and glue them to the body tube. Be sure to match the grain on the balsa with the grain direction indicated on the fin pattern. Align each fin by sighting along the body and adjusting it until the fin is parallel to the body and projects straight away from it. After the glue has dried run a fillet of glue along each of the fin-body joints.

Glue the launching lugs into place as shown in the drawing. Apply glue to the large end of the balsa adapter and insert it into one end of the payload section tube. The nose cone should fit tightly in the other end of the payload tube. If it is too loose wrap its shoulder with tape to increase the diameter.

Attach the shock cord and recovery system as shown in the illustration. Paint the model and apply decals.

Shock Cord Installation



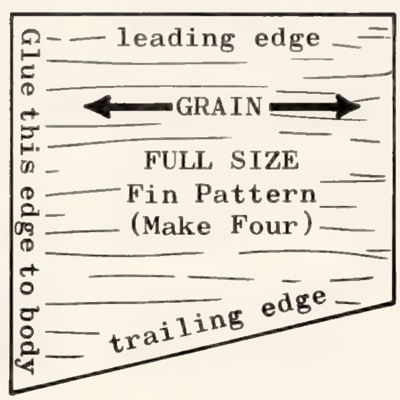
Cut two slits and push section inward. Thread cord through and knot. Restore body tube contour and seal with glue.

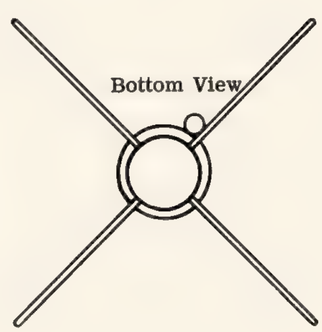
PARTS LIST

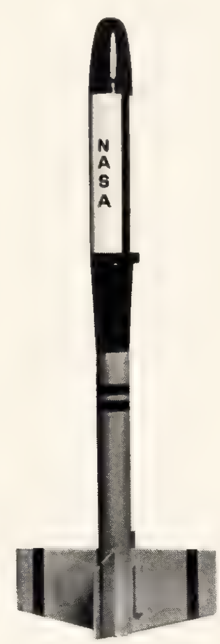
1	Nose Cone	#BNC-50J
1	Body Tube	#BT-50S
2	Launching Lugs	#LL-1A
1	Balsa Adapter	#TA-2050
1	Screw Eye	#SE-1
1	Shock Cord	#SC-1
1	Parachute	#PK-12
1	Body Tube	#BT-20D
1	Engine Block	#EB-20A
	Balsa Fin Stock	#BFS-20

Recommended Engines

1/4A.8-2 1/2A.8-2
A.8-3 B.8-4
B.3-5







Estes Industries Technical Report TR-4

Rear Engine Boost-Gliders

by Gordon Mandell

INTRODUCTION:

These are the preliminary findings of a research program conducted since March of 1962. Some fifty boost-glide vehicles have been constructed to date, and to augment the findings library research in aerodynamics has been conducted. It must be borne in mind that these findings are of a mainly qualitative nature, with expected accuracy in most other cases (i.e.; quantitative findings) about plus or minus 10%, except as specified.

I. THE BOOST PHASE:

A boost-glider is a model rocket which rises vertically in the manner of an ordinary fin-stabilized rocket, and returns in an aerodynamic glide. It is an aircraft and a rocket in one. Let us investigate, then, the design requirements for a vehicle of this type. The first thing we must bear in mind is that we are designing a rocket, which is

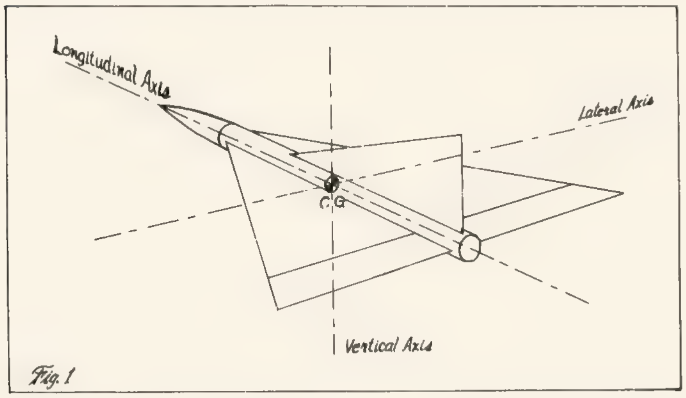


Fig. 1

stabilized by locating the center of pressure behind the center of gravity in the manner detailed in Technical Report TR-1. This is going to have an obvious effect on the boost-glider: Its wings must be located so that they bring the CP of the top view behind the CG by a substantial margin, and also its directional stabilizing surface, the rudder(s), must be located so that it brings the CP behind the CG in the side view.

The distance between the CG and the CP is called in physics a moment - arm, and the stabilizing force exerted by the surfaces, wing and rudder, multiplied by the length of the moment arm, results in the corrective moment. This moment is, obviously, proportional to the force of the air hitting the surfaces, which, in turn, is dependent on two factors: The speed of the rocket and the angle that its longitudinal axis (body) makes with the relative wind. The ideal case of

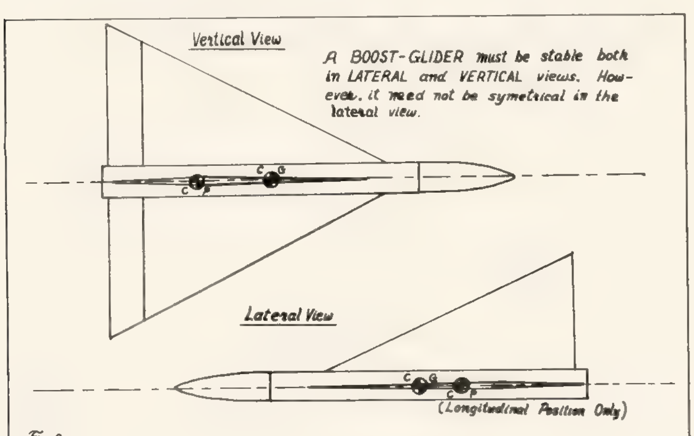


Fig. 2

rocket stability is one in which very little corrective moment is applied because the rocket flies with little oscillation directly into the relative wind. While the air hitting the surfaces at an angle produces a component of force acting perpendicular to the body to push the rocket back into parallel with the relative wind, it also produces a component of force pointing directly rearward from the rocket, and parallel to the relative wind. This latter force is drag, and

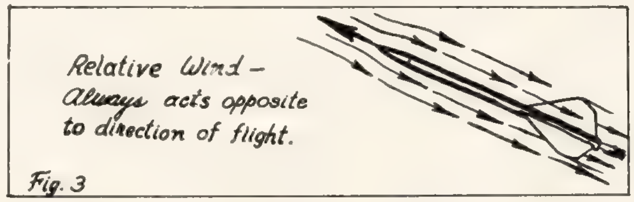


Fig. 3

the more the rocket oscillates, the greater will be both corrective moment (if the rocket is stable) and drag. Because of its large surfaces, it is best to design the boost-glider so that its stability is greater than that needed for most other rockets. Generally the center of pressure should be at least 3/4 the body diameter behind the center of pressure.

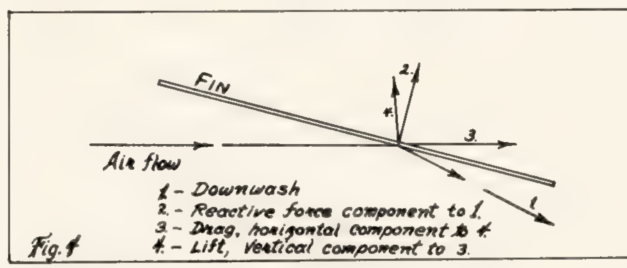


Fig. 4

II. THE GLIDE PHASE:

In glide phase, most rear engined boost-gliders use what is known as the flat - plate effect. (A fully symmetrical airfoil may be used, but it involves some difficulties in construction and alignment. The principles involved in this type of airfoil may be studied in most books covering aerodynamics.) The flat-plate effect simply makes use of the relative wind bouncing off the wing, which produces a component of force which is perpendicular to the wing (see Fig. 5). Since the wing is tilted at an angle to the relative wind, the force will also be tilted at this angle. Thus, when resolved into components parallel with and perpendicular to the relative wind, drag and lift, respectively, are determined for the wing surface.

For any lift to be produced in this manner, the wing must be inclined upward into the relative wind. This is accomplished by means of flaps located at the rear of the wing (in a delta or flying wing design), commonly called elevons. These elevons are tilted up at the rear, which means, by our previously stated principle, that air hitting these elevons will force the rear of the wing down. This, in turn, means that the forward end of the glider is forced up, meeting the relative wind at an angle, and the vehicle glides. Obviously, the extent of this force, called the moment of tail depression, is dependent on the speed of glide, the angle at which the elevons are set upward, and the size of the elevons.

To discover what size of elevon is best for a given glider, we must first take into consideration that there must be some force which makes the glider travel forward in the first place. In glide phase, the engine has been expended, and the only forces acting on the glider are those of air and gravity. After the rocket reaches flight apex and expells its engine, it begins to fall towards the earth. This produces a relative wind which is directly opposite to the direction of travel, i.e.; the rocket is falling down so the relative wind will be up (see Fig. 3). In almost every design imaginable, the CP will remain behind the CG after

ejection of the engine. As a matter of fact, many designs experience a forward shift of CG as the engine ejects. Thus, the glider remains stable as a rocket, and with its corrective moments still effective, the nose turns toward the ground. However, since the elevons have been actuated by this time, the rear of the rocket is forced down by the air acting against them, and thus the nose is forced up and the flat-plate effect suspends the vehicle in gliding flight. In order to glide, the rocket corrective moment must be overcome by the flat-plate effect of the elevons.

Since setting the elevons up at an angle also produces drag, the boost-glider will, in glide, reach a terminal velocity of forward motion and will then keep this velocity rather constant. So we now know that our elevons, to be effective, must produce a depressive force greater than the rocket's corrective force <u>at the terminal velocity of glide</u>.

With these factors in mind, then, we can see that the size of the elevons required depends on: (1) The distance between the CP and the CG of the top view in glide, and (2) the velocity of the vehicle in glide. The latter is itself dependent upon the size and the angle setting of the elevons, being from about five to fifteen miles per hour in the average glider. For a glider of approximately one half to one caliber rocket stability in glide phase, and which has elevons located at the rear of the wing at an average distance from the CG, elevons of approximately 20 to 30 percent of the total wing area are needed for a good, easily adjustable glide. This amount will vary down to about 10% for less stability in glide phase than in powered flight, and up to about 35% for greater stability in glide phase. Any glider requiring more than 35% is not properly designed, and probably posesses an engine located very far to the rear or excessive rocket stability.

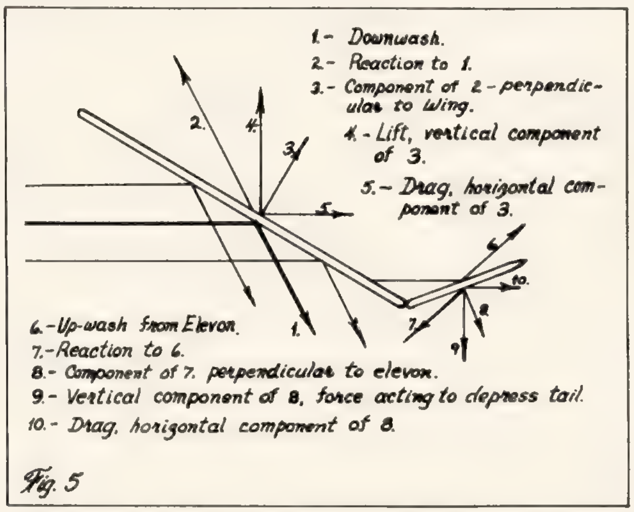


Fig. 5

An interesting variation on elevon-controlled gliders is the canard design. Canard gliders may be constructed in several ways. First, an explanation of "canard" might be in order. A canard is defined as any lateral stabilizing surface (that is, one that prevents pitching) located forward of the main lifting surface. Canards may also provide lift. When equipping canards with flaps, we must remember that, since the canards are forward of the CG, to induce the nose to angle upward we must deflect air downward by means of our canard-mounted elevons. Therefore, while we build rear-mounted elevons to flip upwards at engine ejection, we must construct canard flaps so that they flip downwards at this time. Construction of mechanisms for various types of flap actuation will be covered in Part III. One advantage of canard flaps is that, besides inducing an inclination to the relative wind of the main lifting surfaces, they also provide a small amount of lift themselves, since they deflect air downward and by the principle of action and reaction are acted upon by this air in an upward direction.

Designs which have only canard-mounted elevons usually are of rather high aspect ratio (the aspect ratio is the wing span divided by the average wing width, or chord) than other designs, and experience a slight rearward shift of CG after ejection. Since they have a longer moment-arm through which to act, canard flaps usually do not need to be as large as the flaps in other designs. Canard designs offer slightly more drag than others, and are all but useless when the nose is very heavy, since this shortens the moment-arm through which the flaps can act. Very successful canard designs have been constructed with elevons on both the main wing and on the canards, connected by thread to each other. However, these also suffer when the nose is heavy, and consequently must be built with very light noses.

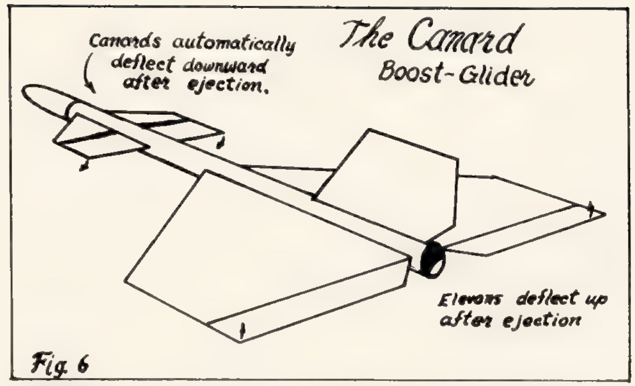


Fig. 6

There is no definite rule as to the best aspect ratio for delta or flying wing designs. It seems that high aspect ratio wings give faster response to thermal currents than low aspect ratio wings. Low aspect ratio wings are slower to recover from dives. However, structural considerations also come into the picture, as we shall see in Part III.

Just about any rudder large enough to give stability as a rocket in a side view is sufficient to directionally control the vehicle in glide. It has been noted, however, that a glider is more susceptible to spiral diving during turns when its center of directional guidance (the center of lateral area of the rudder) is more than 3/4 caliber behind the center of lift (the center of lateral area of the wing in flat-plate airfoil models). This has been found to be at least partially caused by a flow of air crosswise on the forward part of the wing, allowing excessive sideslip and turning, which results in a spinning, nose-down attitude.

A boost-glider will have better resistance to rolling in glide when its center of directional guidance lies above the CG, as when the rudder is located on top of the body tube. There are yet no definite rules for wing-tip rudders and for dihedral angle of lifting surfaces. However, it is known that dihedral angle in moderate amounts improves glide by giving a "pendulum effect" while it does not detract noticeably from rocket performance. The glider need not be symmetrical in side view, as are most rockets.

Another factor to be considered in designing boost-gliders is wing loading. This figure is widely used in professional engineering, and is arrived at by dividing the area of the lifting surfaces by the weight of the vehicle in glide condition (without engine). The higher the wing loading, the greater will be the rate at which the glider descends during glide. Obviously, then, one way to attain a good glide is to use wings as large as possible and body tubes as light as possible. However, this too is subject to structural limitations. Increases in lift may also be obtained by increasing the angle of attack to the relative wind. However, this also increases drag, and past a certain point drag slows the vehicle to the point where lift begins to decrease again.

<u>III. STRUCTURAL AND FLYING PRACTICE:</u>

It would indeed be gratifying if we could use as high aspect ratios, as large surfaces, and as light construction as is dictated by ideal theory. Unfortunately, structural practice is controlled by the forces which a boost-glider must withstand in flight, and the dictates of these stresses often run opposite to those of theory.

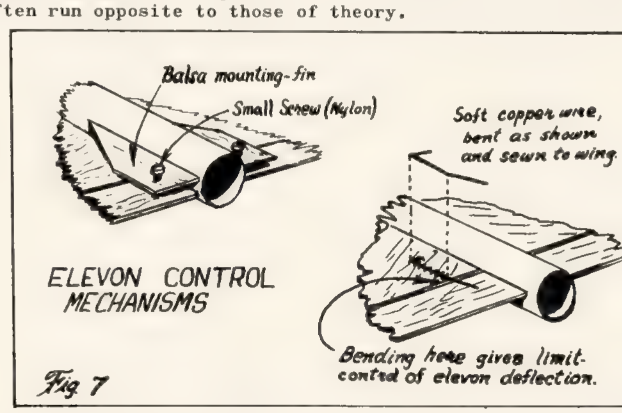


Fig 7

The extent of these forces, caused by acceleration and air drag, is dependent upon the size of engine used and the number of engines or stages. The greater the acceleration and the duration of that acceleration, the greater the speed and hence the drag. In first considering the forces acting

on the aerodynamic surfaces, at constant acceleration the force will vary as the square of the velocity, as stated in the equation for drag. In general, a balsa thickness of 1/16" has been found adequate to withstand all air forces produced by Series I engines, provided the aspect ratio of the wing or other surface does not exceed about 4; that is, if the span of the wing divided by the width, or chord, does not exceed this number. Above this number, the wind begins to twist the surface, producing the same effect as warp.

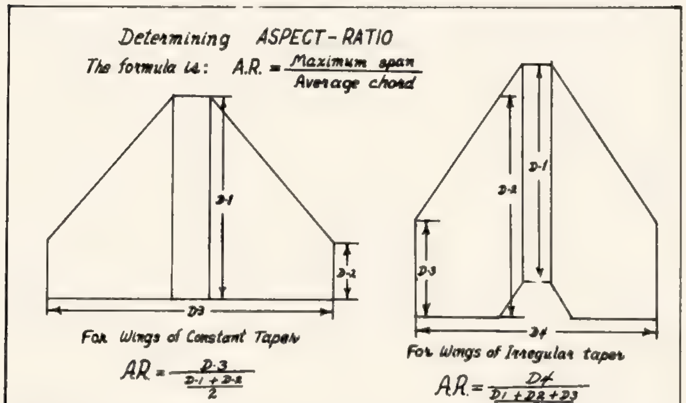


Fig. 8

Also of importance is the effect of acceleration during boost. A one-ounce model's wings may weigh 23 times their normal weight for a short time during boost. For this reason, wings should be kept as light as possible consistent with adequate aerodynamic strength. Also, wings which have their CG closer to the body tube, or with low aspect ratios, will be more resistant to being torn loose from the body tube by acceleration forces.

The strongest wing-body joints are possible when the wings are joined together with each other and the body at the underside of the body and the connection reinforced by 1/2 inch wide strips running parallel to the body at the joint. The grain on these strips should be at a right angle to the grain of the wings. The wing-body joint may also be strengthened by the use of gauze or silk reinforcing, by using thicker balsa for the wings, and by using the longest practical wing-body joint.

Internally-operated elevon actuators, such as pistons driven by the ejection gases, have been tried, but have been found to be not as reliable and more difficult to construct than those actuated by the ejection of the engine. The simplest system to employ is one in which a piece of wire or balsa is held depressed by the engine casing.

When one end of the actuator is held in place by the engine, the other end of the stiff wire or balsa is attached to the elevon, so that the elevon is in neutral position with the casing in place. A piece of elastic thread is fastened to the elevons in a manner which will pull them up (or canard flaps down) when the engine leaves the body tube and allows the wire depressor bar to travel to the actuating position (see Fig. 9). When the depressor bar runs rearward from the elevon to the casing, it should be held down by the casing; when forward it should be held upward by the casing, which will push the elevon down to neutral.

Systems have been tried in which the arrangement is one continuous bar fastened to both wings, and where there are two bars, one for each wing. The latter has been found to be more practical, as it allows individual setting of each elevon. Setting is accomplished either by a small balsa brace with a set screw which, depending on how far the screw is turned up or down, will regulate the elevon accordingly, or by a single-strand, soft copper wire, which can be bent to the degree of elevon desired, and will stop the elevon's upward travel depending on how far it is bent.

With early types of gliders, in many cases the engine was set forward of the aft end of the body tube to move weight forward further. This, after a number of firings, tended to burn away some of the body tube. This was corrected by the application of a solution of sodium silicate (waterglass), a chemical used as a flameproofer and egg preservative, to the inside rear of the body tube. Waterglass has the disadvantage of blistering and ablating into the exhaust gases, leaving a flaky residue and unsightly appearance, as well as imparing the fit of the engine into its mountings. For applications involving the protection of elevons or rudders from exhaust gases, aluminum foil was found much more satisfactory, the foil being glued to the surface in question.

An even better alternative involves the use of an expended engine casing to shift weight forward. The nozzle is drilled or chipped out of the old casing, and the casing is then glued or taped to the front of a live engine. Thus, when the engine is ejected, it will take the expended casing with it, lightening the nose for good glide. This method gives much greater boost stability. The current world's record holder of glide duration was equipped in this manner.

For the early recessed-engine models, and for multi-staging, it has been found necessary to arrange some system by which the depressor bars will not interfere with the stage joint. Obviously, a system using depressor bars which extend rear of the body tube to be operated by an engine which sticks out of the rear of the tube is impossible in recessed engine models, and interferes with mating of the stages. Instead, ports are cut in the body tube forward of the elevons, and the depressor bars are operated through these ports. This adds to drag and is more difficult than external-bar arrangements, but is the only proven method of meeting these special requirements. This method is also used to operate canard flaps, which are located far forward on the body.

Ports too near the front of the engine casing have caused ejection failure. In general, ports should not be cut less than about 3/4 inch to the rear of the point where the forward end of the engine casing will rest in flight. In this way, pressure does not escape from the ports at ejection charge activation.

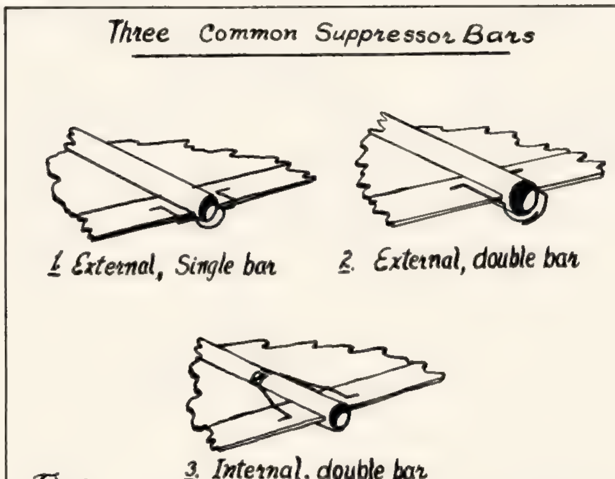


Fig. 9

Elevons in the rear and canard flaps in the front can be operated together if the rear elevon actuator is made according to standard practice, and then strands of ordinary thread are attached to the elevons, as far to the rear as possible. The thread is then brought forward, crossed over the body tube, and attached to the canard flaps. Thus the left elevon will, when released, lower the right canard flap, and the right elevon the left canard flap. The canard flaps are, of course, equipped with elastic thread to pull them down when the thread is slackened, which happens when the rear elevons are actuated. Gliders using this system can be made to stay in the air for more than two minutes, single staged.

Research on cluster-engined boost-gliders has so far shown that they are not as practical to build and fly as single-engined gliders, due to the large concentration of weight at the rear of the body. This requires that rocket stability be increased by placing the wings very far to the rear, with the result that the CG moves forward a considerable distance at the ejection of the engines. This in turn makes extremely large elevons a necessity.

CONCLUSION:

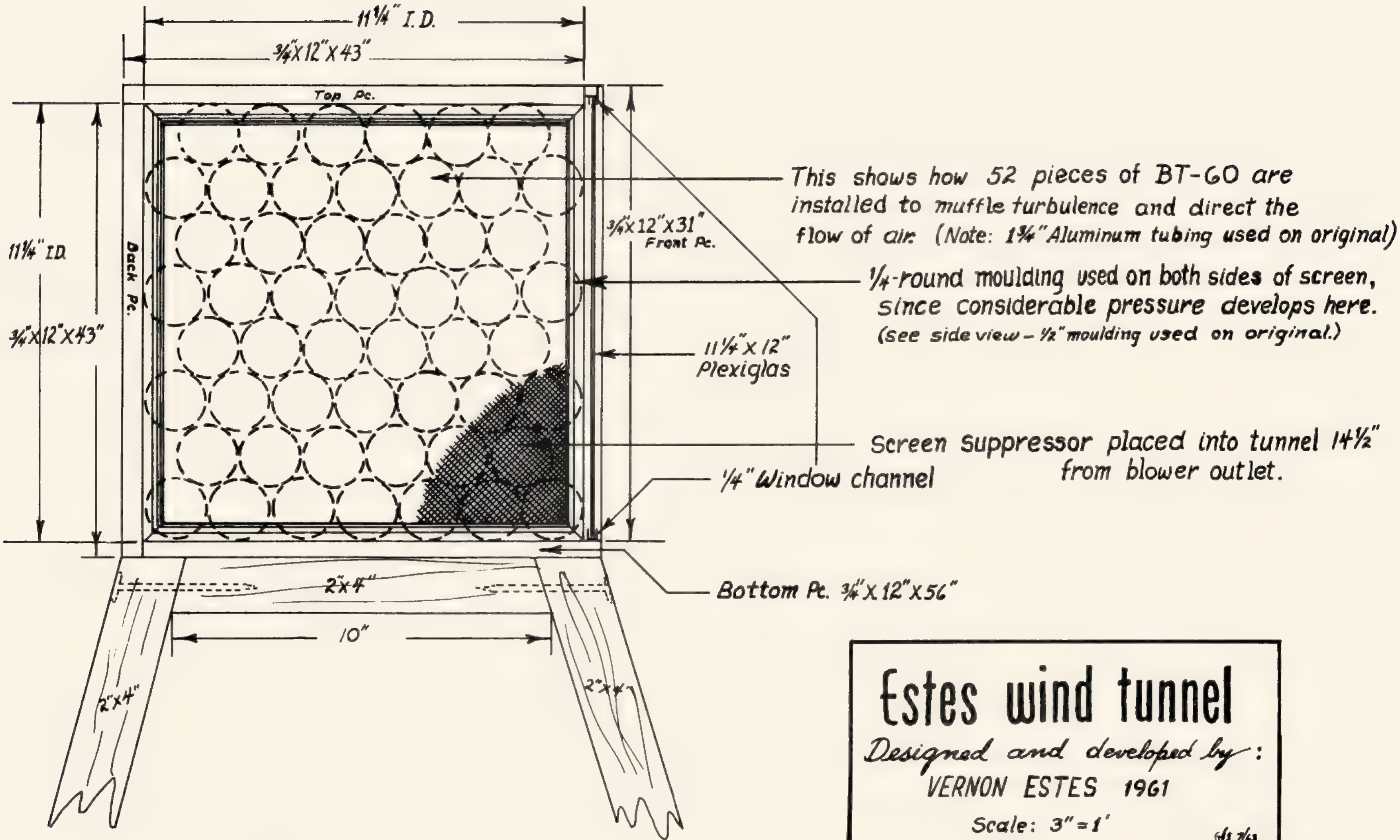
The design and construction of good boost-gliders is still an art, and requires a high degree of skill in the modeler. But there are few things in any area of modeling which can compare with the satisfaction of building and flying a good glider. This is a field with a genuine challenge for the builder, and those who accept the challenge will find themselves plunged into a search for new methods, materials, and principles that results not only in a greatly expanded knowledge of the physics of flight, but also in contributions to the entire art of model rocketry.

Estes Industries Technical Report TR-5

BUILDING A WIND TUNNEL

Published by Estes Industries,
Box 227, Penrose, Colorado

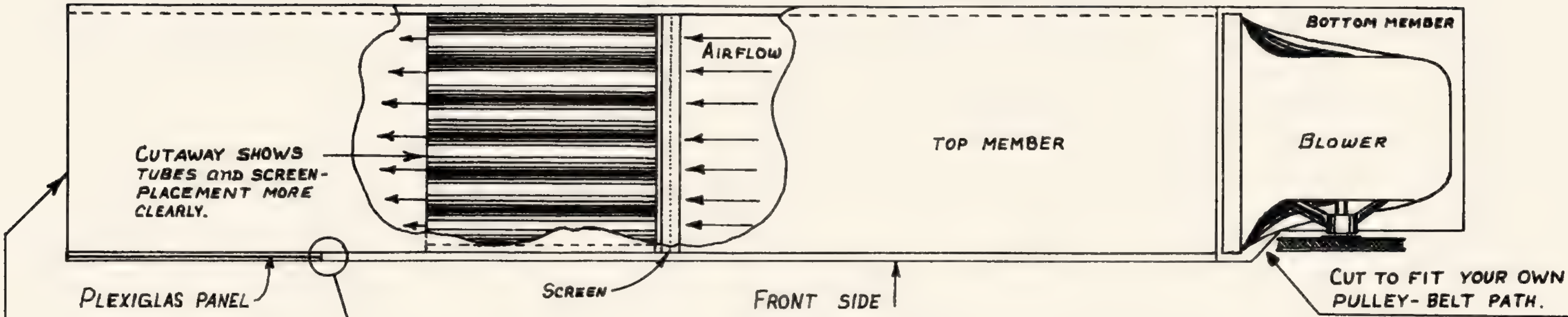
OBSERVATION - END VIEW

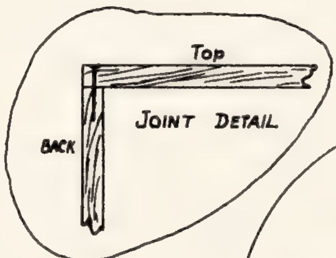


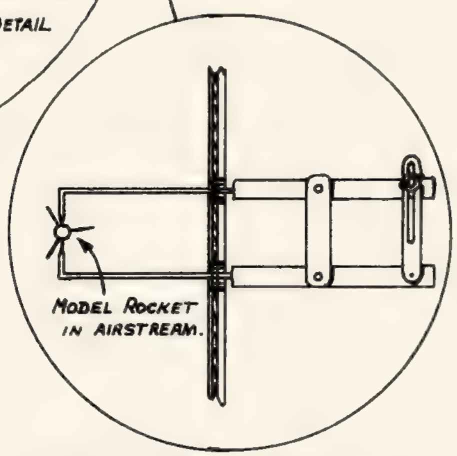
Approximate wind velocity
22 feet per second

Top View

Planview..... Scale: 2"=1'







Use of low-friction Pivot-points is shown here, protruding through the slots adjacent to Plexiglas "window"

BILL OF MATERIALS:

1 -	3/4" X 12" X 31".....	FRONT SIDE MEMBER.
2 -	3/4" X 12" X 43".....	TOP MEMBER AND BACK SIDE MEMBER.
1 -	3/4" X 12" X 56".....	BOTTOM MEMBER.
1 -	11 1/4" X 11 1/4"	STANDARD WIRE SCREEN, 8 MESH.
8 -	1/2" X 11 1/4"	QUARTER-ROUND MOLDING FOR FRAME ON SCREEN.
52 -	11" SECTION.....	B-T 60 TUBING.
1 -	11 1/4" X 12" X 1/4".....	PLEXIGLAS SHEET.
2 -	1/4" X 12"	ALUMINUM WINDOW CHANNEL.
2 -	2" X 4" X 10"......	TOP LEG-LAND.
2 -	2" X 4" X 19 3/4".....	LEG CROSS-BRACE.
4 -	2" X 4" X 37 1/4"......	LEG.
1 -	2" X 4" X 53"	LONGITUDINAL LEG-BRACE.

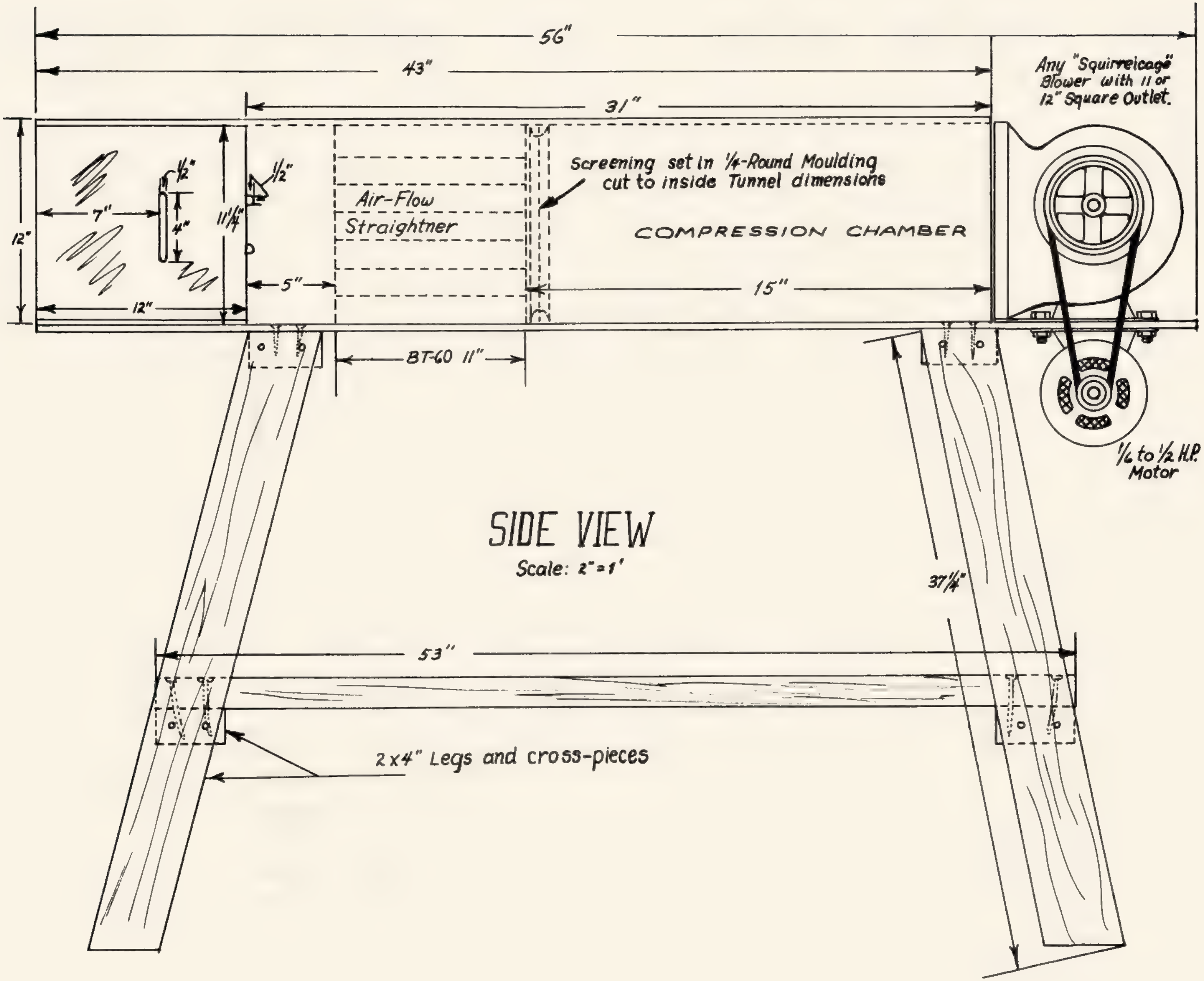
MISC. NAILS - WOODSCREWS - BLOWER AND MOTOR-MOUNTING BOLTS.

1 - SQUIRRELCAGE BLOWER WITH 11" OR 12" OUTLET.

1 - 110 V. ELECTRIC MOTOR, 1/6TH TO 1/2 H.P.

PLEASE NOTE: THOUGH THIS UNIT IS IDEAL FOR STABILITY TESTS, IT IS NOT RECOMMENDED FOR CHECKING DRAG. FLOW-VELOCITY IS TOO LOW AT 22 FEET PER SECOND.

OPEN END PERMITS TEST OF LARGER MODELS...... BUT, RESULTS MAY BE INCONCLUSIVE DUE TO "OUTSIDE AIR" MIXING INTO STRAIGHT FLOW, CAUSING TURBULENCE AT VARYING DISTANCES FROM TUNNEL-END. SUGGEST NOSE OF VEHICLE UNDER TEST BE PLACED WELL INTO TUNNEL.



SIDE VIEW

Scale: 2" = 1'

Wind Tunnel Assembly Instructions

The Estes Wind Tunnel was designed especially for checking the stability of model rockets, and can be easily built by the modeler with moderate experience in woodworking. Modifications in this wind tunnel design to allow the use of materials the rocketeer already has on hand should not hurt its performance to any great extent.

The blower used in this wind tunnel is a standard furnace blower, and it should be possible to obtain one from your local plumbing-heating contractor for a reasonable price if you specify a used one and tell him what you are going to use it for. The motor can be almost any 1/6 to 1/2 horsepower, 115 volt unit. The ratio of the sizes of the pulleys will depend on the output speed and power of the motor and the rated speed of the blower.

The first step in assembly is to cut out the front, back, top, and bottom pieces from 3/4" plywood. These pieces should be cut out carefully so they will match up properly when attached to each other. Sand the four pieces on all sides and then nail them together to form the tunnel body as shown in the plans. Use 6d finishing nails, and apply white glue to the joint before pressing the wood together and nailing. Support the tunnel body during this operation to insure that it remains perfectly square.

Paint the inside and outside of the tunnel with enamel paint. Be especially careful to give the inside of the tunnel a smooth finish to reduce turbulence and give a more even air flow.

Nail four pieces of quarter round moulding into the tunnel to form the rear (blower end) frame for the screen as shown in the plans. Press the screen into position and nail the other four pieces of moulding into place to form the front frame. (The screen should be nailed in place without any moulding if minimum turbulence is desired.)

Cut and drill the bottom piece to match the mounting holes of the blower and the motor. Be sure that the holes are drilled to position the blower firmly against the rear of the tunnel. The blower should be adjusted so the flow is as even as possible.

Cut, miter, and sand the 2 x 4 pieces for the tunnel stand. Nail the stand together using 16d nails. Nail the stand and the tunnel together, then paint the stand.

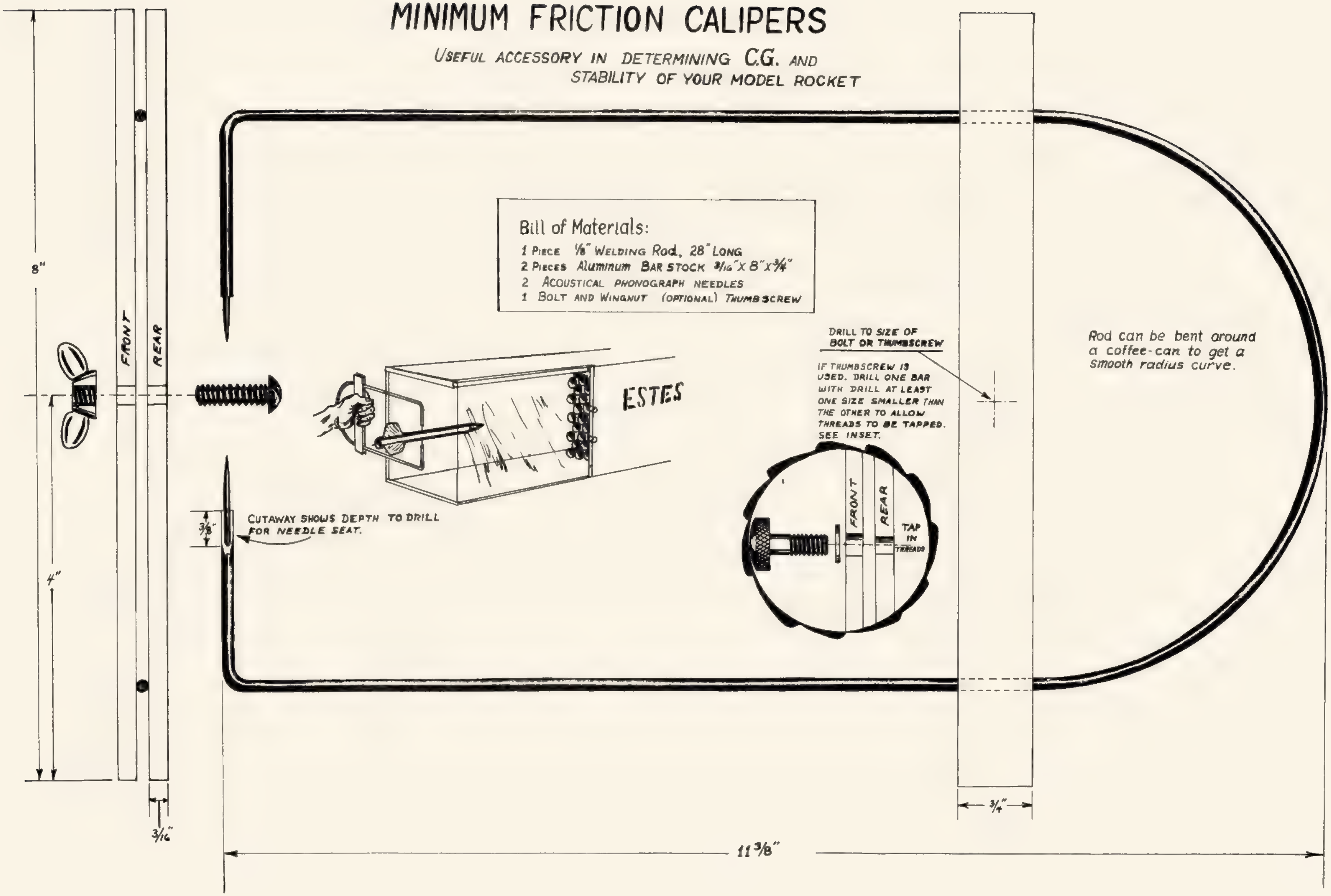
Mount the blower, motor, and belt at the rear of the tunnel. The exact mounting procedure will vary with the type of motor and blower. Make sure the belt has a firm grip against the pulleys on both blower and motor.

Put the flow straightener tubes in place in the tunnel. These tubes should have a thin wall, and either metal tubing or BT-60 may be used. When all tubes are in place the assembly should make a tight press fit inside the tunnel body. (There are several other possibilities for the flow straightener. It may, for example, be made from heavy posterboard arranged to form a rectangular grid.)

Make a belt guard to keep fingers out of the moving parts of the wind tunnel. This guard should be designed to fit the pulleys and belt used on your wind tunnel, and may be made from sheet metal, cardboard, plywood, or other materials which may be available. Attach the aluminum window channel at the front of the tunnel. Slide the plexiglas window into place, and the wind tunnel is completed.

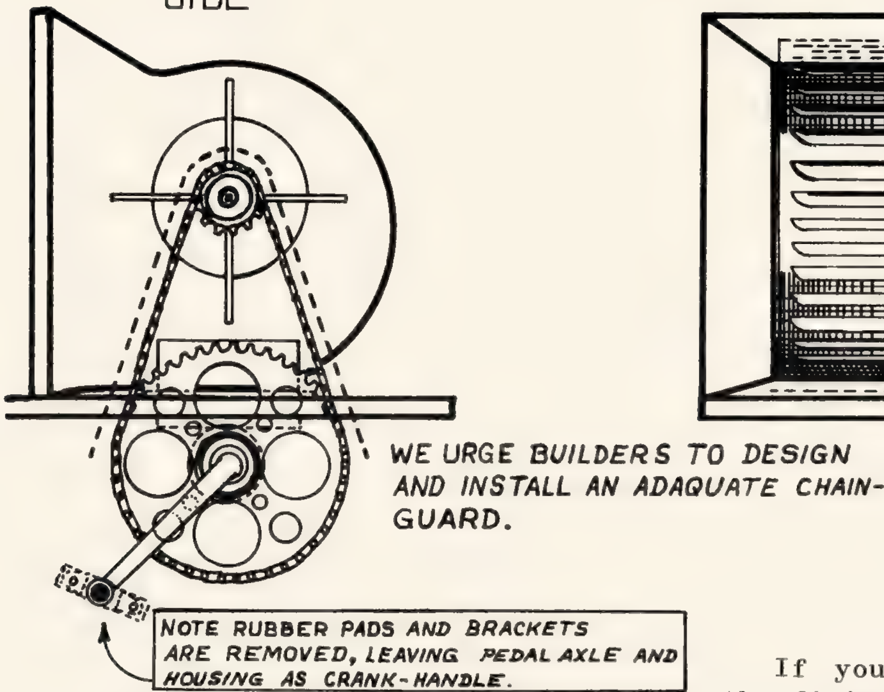
MINIMUM FRICTION CALIPERS

USEFUL ACCESSORY IN DETERMINING C.G. AND STABILITY OF YOUR MODEL ROCKET

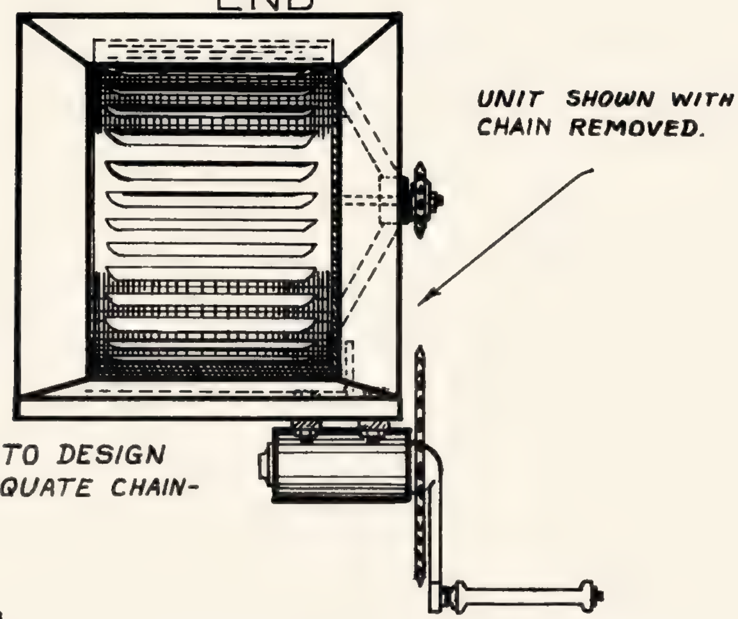


HAND-POWER for your MODEL WIND TUNNEL

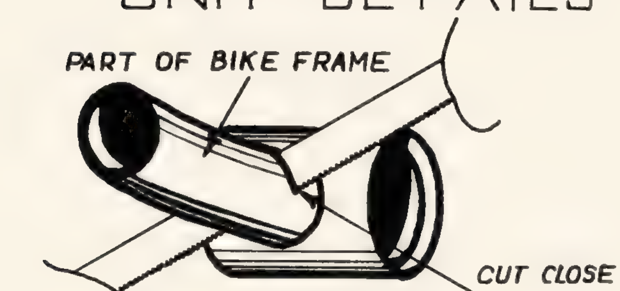
SIDE

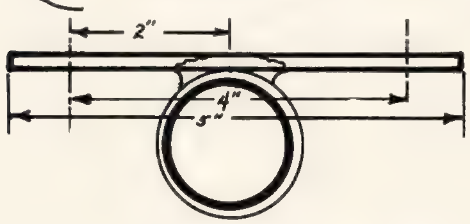


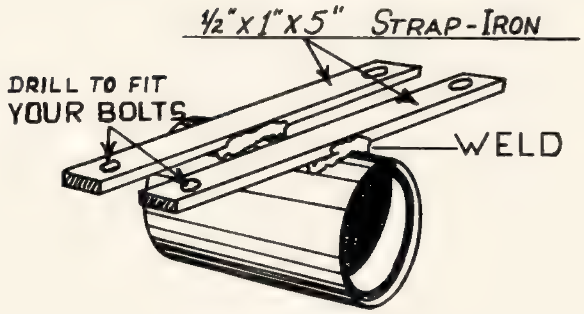
END



BOTTOM "PEDAL"-UNIT DETAILS







If your wind tunnel is to be used on the firing range, chances are that electric power won't be available to run a motor. To allow the range control officer to check any rockets of questionable stability, you might build your wind tunnel for hand power.

The parts for the drive unit on the hand powered wind tunnel can be salvaged from a used bicycle. The bearing carrier for the pedal-sprocket unit is cut from the frame, and the pedal on the side away from the sprocket is cut off completely. The mounting for the rubber blocks on the remaining pedal are removed to make a hand crank.

Two pieces of strap iron are welded to the bearing carrier as in the drawing. This unit is then mounted at the rear of the wind tunnel under the blower. The sprocket on the blower can be one from the rear wheel of the bicycle, although a smaller sprocket will give a higher speed. Be sure that the teeth on both sprockets fit the chain. The chain should be adjusted to fit fairly tightly around the two sprockets (about the same fit as for a bicycle). Design and install an adequate chain guard to protect the operator.

Estes Industries Technical Report TR-6

Cluster Techniques for Model Rockets

A common technique in the development of rockets to carry large payloads is the use of a cluster of smaller engines to obtain a high thrust level. Typical of this method are NASA's Little Joe, Saturn, and Nova launch vehicles.

Clustering can be used with model rockets to give excellent results. However, if this method is to be used successfully, the rocketeer must use the right techniques and apply them correctly.

Experience has shown that with present techniques clusters of more than 4 engines are not practical. While rockets using more engines have been flown, they are not very reliable. The techniques described in this report have been developed and used almost entirely for clusters of three engines. These methods may, however, be adapted to 2 or 4 engines without too much difficulty.

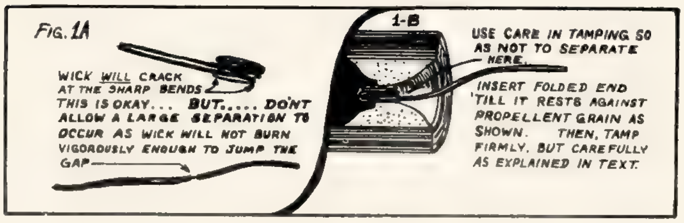
IGNITION

One of the first questions a rocketeer asks when he starts learning about clustering is "How do I ignite all the engines?" There are several methods of doing this, each of them quite satisfactory <u>when used correctly</u>.

THE JETEX SYSTEM

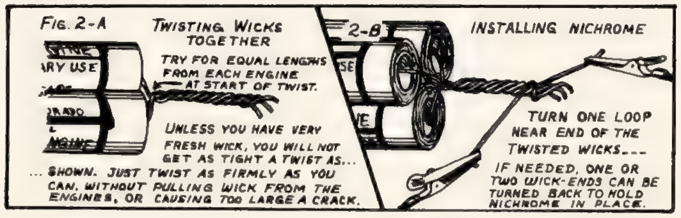
The oldest method for igniting a cluster of model rocket engines is the Jetex system. Equal lengths of Jetex wick are inserted into the nozzles of the engines. The free ends of the wick are twisted together and a length of nichrome wire is wrapped around the wick to ignite it.

If the Jetex wick has been installed correctly, it will burn up the different strands and ignite the individual engines at about the same time. Before trying this system, though, it is important to understand all the precautions which must be taken.



Three 2-1/3 inch lengths of Jetex wick are cut. One end of each piece of wick is folded 5 to 7 times as in the illustration. Be careful not to break any of the coating from the wire, or the wick will not burn evenly. These pieces of wick are inserted into the nozzles of the engines and pushed up into place against the propellant with the point of a pencil or a ball-point pen. It is very important to avoid breaking the wick and equally important to get the wick all the way into the nozzle and against the propellant grain. It is also important to get the wick tight enough in the nozzle so that it will not readily fall out.

With the Jetex in the engines and the engines in the rocket, the next step is to join the separate wicks together (see fig. 2). The distance from each nozzle to the point where the wicks are twisted together must be equal and must be as short as possible.



If all these preceding steps have been taken carefully and correctly, it is time to wrap a length of nichrome wire around the twisted portion of the wick, being careful the wire does not short-circuit against itself. Then put the rocket on the launcher, attach the microclips to the nichrome on opposite sides of the loop around the wick, give the countdown, and launch.

Ninety nine and 44/100ths percent of all cluster ignition failures are due to lack of care in installing the igniters. If the rocket veers off course during powered flight, chances are that one engine ignited earlier or later than another or failed to ignite at all. Since few people are 100% accurate all of the time, it is necessary to build cluster rockets with an extra large margin of stability to counteract the effects of imbalanced thrust.

Because of the difficulty in igniting all three engines at exactly the same instant, this system is not recommended for use with 1/2A or smaller engines, nor is it recommended for use with Series II engines. Rockets with the small Series I engines are more apt to go off course if there is any difference in their firing time, while the takeoff acceleration with Series II engines is apt to pull the wick out of the nozzle of any unignited engine, making ignition of all three engines a very rare occurance.

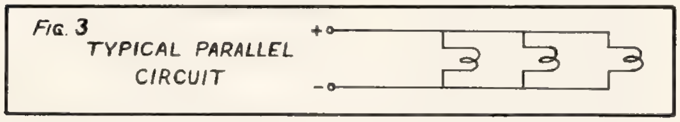
The particular disadvantages of the Jetex system led to a search for other, more practical means. While no perfect systems have been developed nor appear likely to be developed, there are two other systems in use,

each with its own advantages and disadvantages which enable the rocketeer to use the system which best fits his needs.

THE DIRECT ELECTRICAL SYSTEM

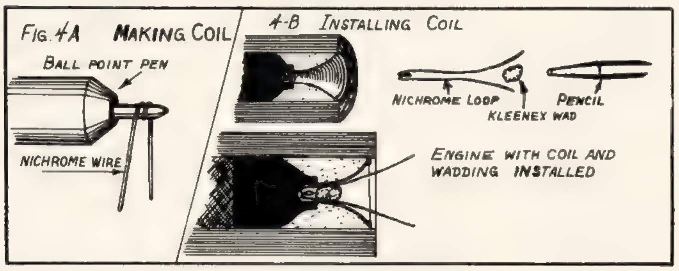
The direct electrical system is potentially the most reliable of all methods of cluster ignition. However, it also requires the most care of any system. If proper care is not exercised, it can be completely frustrating.

In this system the engines are prepared with standard nichrome igniters. The igniters are connected in parallel to the firing system so that when the launch switch is pressed current flows to all igniters at once.



If everything has been done correctly, all three engines will fire at the same instant and the rocket will roar skyward. However, if there were any errors in the preparation of the rocket and the firing system, one or more of the rocket's engines will fail to ignite.

The first requirement with the direct system is that the nichrome igniters in the individual engines be installed correctly. There are several points to remember when installing nichrome igniters and many rocketeers fail to apply these points. It is first of all necessary to get the coil of the igniter against the propellant grain (9/16" from the rear end of the rocket engine). If this is not done there is little possibility of the engine igniting. If the engine is to ignite there must be no short circuits in the igniter.

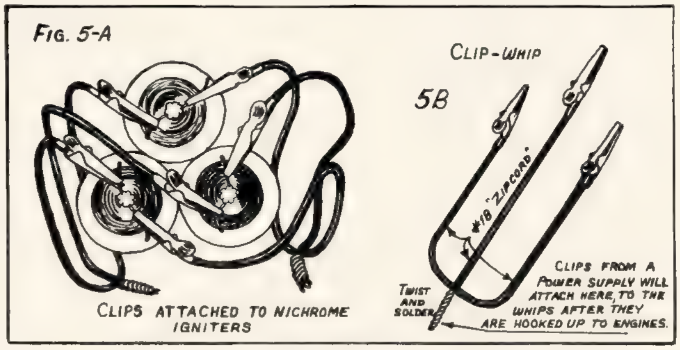


The loops of the coil must be spread far enough apart so there will be no possibility of one part touching another, even with the kleenex tamped in place. The parts of the nichrome leading to the coil must come out on opposite sides of the nozzle with the kleenex tamped in between them.

Even if the nichrome igniters are installed with the coil touching the propellant grain and no short circuits anywhere in the igniter, the battle is not quite won. After the engines are installed in the rocket it is necessary to connect the igniters in parallel to the firing system (See figures 3 and 5.) The microclips must be connected as far up into the nozzle as possible to give a minimum length of nichrome between them. Under no circumstances should the microclips be allowed to touch each other.

This writer has experienced the best success with this ignition system by fabricating a "whip" as illustrated and attaching the microclips to the igniters before placing the rocket on the launcher. The jaws of the clips are first cleaned carefully with sandpaper to assure a good electrical connection. The clips are then attached to the igniters, a clip from one whip to one end of the igniter, a clip from the other whip to the other end of the igniter. With the clips in place, pieces of masking tape are applied at all points where there is any possibility of the clips touching each other.

With this maze of wires in place, the rocket is gently placed on the launcher, and the leads from the firing system are attached to the remaining leads of the whips. The firing system used with this method of ignition has to have plenty of electrical power. A 12 volt car battery in good condition will provide the necessary power provided that no more than 18 feet of #18 two conductor wire is used between the battery and the rocket and provided all connections, including those to the battery, are good. Flashlight cells will not provide enough current. (If all wiring, etc. is done carefully, 12 or more size D photoflash batteries in series will normally provide enough power to ignite the rocket.)

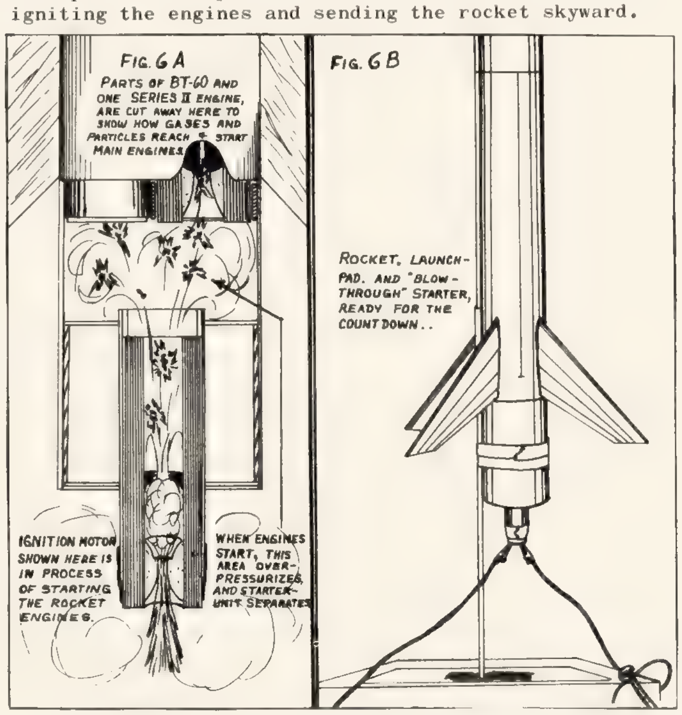


If all steps have been carried out correctly, the rocket can be launched. One of the main advantages of this system is that it can be used successfully with all types of engines, Series I and Series II.

THE IGNITER MOTOR SYSTEM

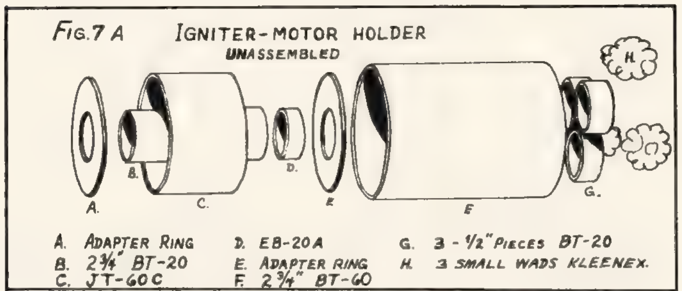
The third system is reliable only when used with Series II engines. This method, known as the igniter motor system, uses a single 1/4A.8-0 engine in a special holder, secured to the launcher, to ignite the cluster of B3 engines in the same way that a lower stage ignites an upper stage.

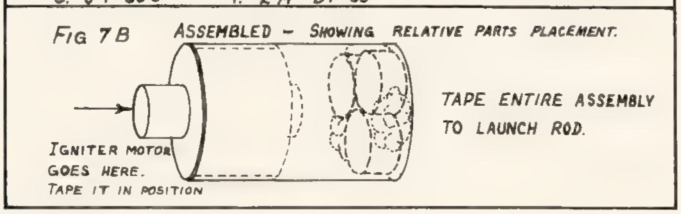
The workings of this system can be seen in figure 6. The 1/4A engine is mounted in the center of a tube of the same diameter as the rocket's body. The tube with the igniter motor is taped to the launcher, and the rocket is lowered into position so that the rocket's body fits exactly over the top of the tube holding the igniter motor. The 1/4A engine is ignited electrically, fires for about .15 second, and then the forward wall of the propellant charge ruptures, hurling hot gases and particles up into the nozzles of the cluster, igniting the engines and sending the rocket skyward.



With this system it is necessary to allow an unobstructed path for the ignition gases from the igniter motor to the nozzles of the cluster. Only Series II

engines can be used in the rocket itself, since the nozzles of other engines are too small to give reliable ignition. It is also important to be sure that the igniter motor and its holder are securely fastened to the launcher.





TYPES OF ENGINES

Since there are so many different engines available to the modeler, the selection of the best one to use in his cluster rocket can become difficult. If maximum performance is desired from a single stage rocket and the Jetex ignition system is used, the proper engine type will generally be the B.8-4. If a 3 engine cluster rocket weighs under 4.5 ounces with engines in place, B.8-6 engines may be used.

To determine whether a particular set of engines is satisfactory for use in your rocket, use the Rocket Engine Selection Chart in the Estes catalog. Maximum thrust and total impulse for one engine are multiplied by the number of engines to provide the figures for the cluster. The same procedure should be followed with the maximum rocket weights.

The use of Series II engines gives certain advantages. The high takeoff acceleration stabilizes the rocket quickly, generally resulting in a straighter and higher flight than is obtained with Series I engines. Payload capability is also increased considerably.

LAUNCHERS

Because of their greater weight and sometimes imbalanced thrust, cluster rockets put considerably more strain on the launcher than do smaller rockets. The standard Electro-Launch is recommended for rockets weighing up to 6 ounces using either the Jetex or the igniter motor systems for ignition. However if the base of the launcher is weighted down with a pair of bricks and the two-piece rod is soldered together, rockets weighing up to 9 ounces may be launched. If, in addition, a 48" length of 1/8" or larger piano wire or other steel rod is substituted for the two piece rod, rockets weighing up to 16 ounces may be launched safely.

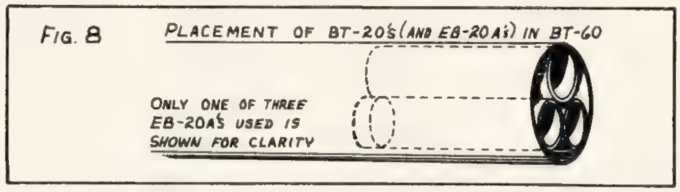
Generally a rod longer and thicker than that needed for single engine rockets is preferable for launching cluster rockets. The thicker rod is less apt to bend or whip as the rocket ascends, and the longer rod will guide the rocket farther, giving the rocket higher speed and greater stability when it leaves the rod. Rockets launched from heavier and longer rods are less apt to veer off course due to imbalanced thrust and will weathercock less due to their greater airspeed when they leave the rod.

ENGINE RETAINING

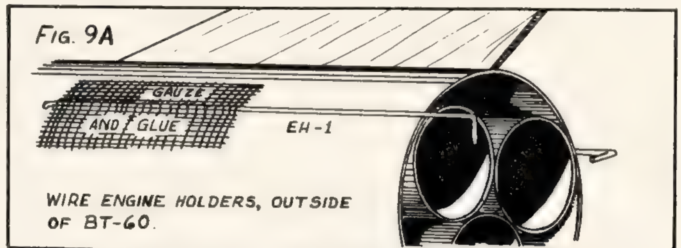
The method of holding the engines is important in any cluster rocket. Not only must the engines be held securely, but they must be aligned with the axis of the rocket so they work as a unit and exert all their thrust in propelling the rocket rather than work against each other. In addition, the engine retaining system must seal the rear of the rocket so the ejection charge or upper stage ignition charge cannot leak out without doing its job.

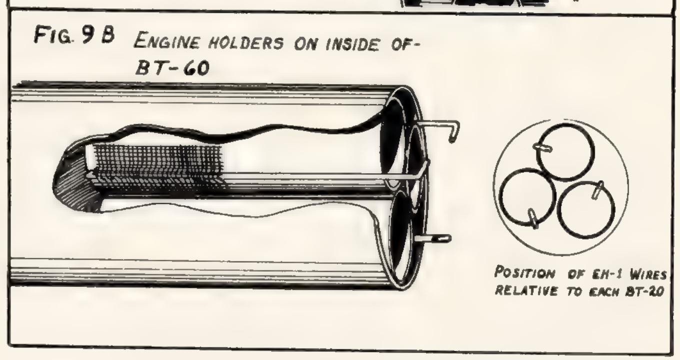
There are two main systems for holding the engines. In the one, the functions of positioning, aligning, and sealing are built into the rocket. In the other, the engines are glued or taped together to align them.

In the first system body tubes just larger than the outside diameter of the engine (BT-20) are glued together and are glued inside the rocket's body (BT-60). These are positioned to handle the alignment of the engines. The spaces between the tubes are then filled with a fillet material such as tissue paper and glue, balsa putty, etc.

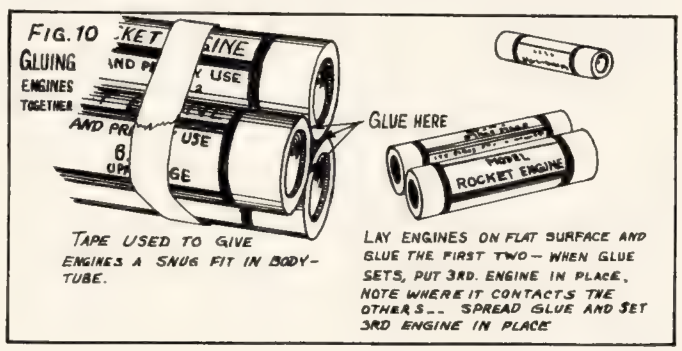


To keep the engines from moving forward during acceleration or backwards at ejection, they must make a tight friction fit in the holder tubes. This may be accomplished by wrapping the engine with tape until it takes considerable effort to push it into position. The other alternative is to use wire engine holders as shown in fig. 9. These make the replacement of engines considerably easier. They must, however, be positioned carefully so they do not interfere with the fins.





In the second system the engines are first glued or taped together, and then inserted into the rocket body. It is usually easier to obtain and maintain correct alignment by gluing the engines together than by taping them together. Enough tape is then wrapped around the outside of this group of engines to give a very tight



friction fit inside the rocket body. Finally, facial tissue or similar paper is tamped tightly into all holes around and between the engines to seal the rear of the rocket and control the ejection gases. (See fig. 11.)

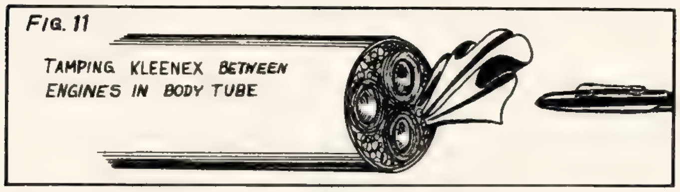


FIG. 11

Some experiments with mounting engines in cluster rockets at an angle to create spin have been tried. However, it appears that spin fins are more effective and more reliable.

RECOVERY SYSTEM

Since the cluster rocket is larger and heavier than the conventional model rocket, its recovery system must be designed to withstand greater stresses than those normally encountered in a model rocket. The recovery system in a cluster rocket almost always uses at least one parachute; other devices have not yet proven practical. Generally two parachutes are used on rockets with large payload sections, one parachute on rockets with no payload section or just a small one.

On rockets with large payload sections two parachutes give more reliable recovery, since there is no possibility of the heavy payload section breaking the shock cord at ejection and no possibility of its snapping back and tangling in the parachute of the lower section if it is completely separate. Cluster rockets without payload sections are best recovered with a single parachute. The nose cone alone is too small to require a separate parachute, and will not put the strain on a shock cord that a 4 oz. payload section would.

Parachutes are normally attached directly to a screw eye in the base of a payload section with no shock cord between the parachute and the payload section. To reduce the possibility of fin breakage on landing the shock cord on the lower or propulsion section of the rocket is often attached to the outside of the body of the rocket near the engines. This is done by gluing one end of a string in a hole in the body about 1" from the rear end and tying the other end of the string to the shock cord. The string should be long enough to reach up the body and into the front end of the tube (see fig. 12).

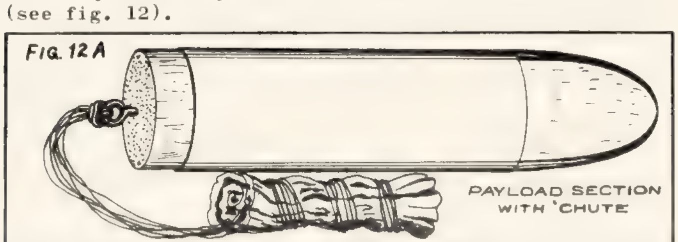


FIG. 12 A

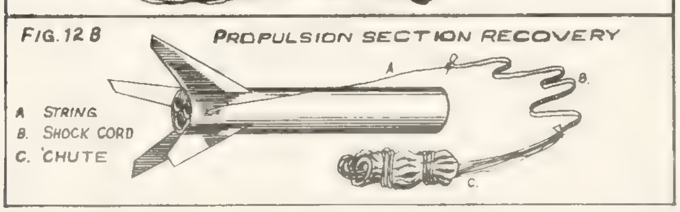


FIG. 12 B

The best way to protect parachutes from the heat of the ejection charge is to use wadding and plenty of it. The wadding should be flameproofed. Flameproof cotton or flameproof tissue paper will work, but rock wool, available from most lumber yards, gives the best results. Pack enough wadding into the rocket to fill it for a distance equal to at least 1-1/2 times the diameter of the body. The wadding whould be fairly tight against the sides of the tube to give an effective seal.

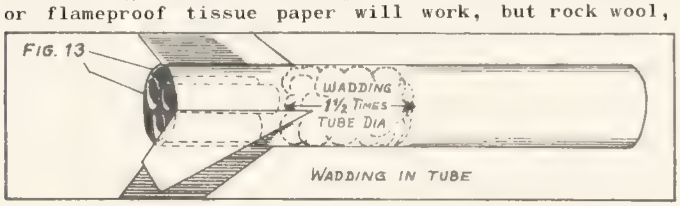


FIG. 13
WADDING IN TUBE

The size of the parachutes should be in keeping with the weight of the rocket. Parachutes larger than 18" will rarely be needed. Normally a 16" to 18" parachute on the lower section of the rocket and 12" to 16" parachute on the payload section will be sufficient.

STABILITY

The fins of a cluster rocket are one of the most critical areas in its construction. They must be large enough to keep the rocket stable even if the engines fire at different times and even if one or more engines fail to ignite. The fins must also be strong enough to hold up to all aerodynamic stresses against them and to withstand landings against rocks and pavement.

The best fin material for cluster rockets is 1/8" thick balsa sheeting (BFS-40). The fins must be cut out so the grain of the balsa follows the leading edge of the fin. The edge of the fin that is to be glued to the body must be straight to give a strong enough glue joint. This requirement is best filled by wrapping a sheet of sandpaper around the body and passing the fin forward and back on the sandpaper several times.

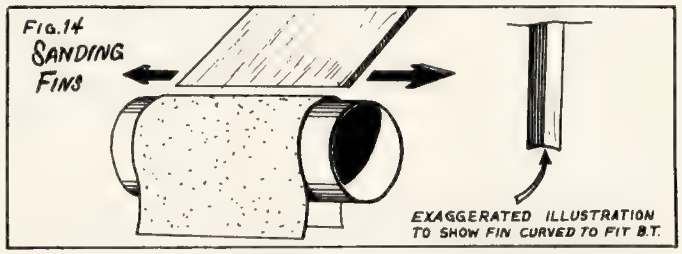


FIG. 14
SANDING FINS

When the fin positions have been marked on the body tube and the fins sanded, they can be glued in place. For best results, apply only a very thin line of glue along the inside edge of the fin. Press the fin into position against the body, and hold it in place for a couple of minutes. Then repeat this procedure with the other fins. After the glue has dried, reinforce each joint by applying a fillet of glue in the corner between fin and body as in fig. 15. The rocket should be balanced on its side (but no pressure should be put on the fins themselves) while the glue dries so it will not flow out of position.

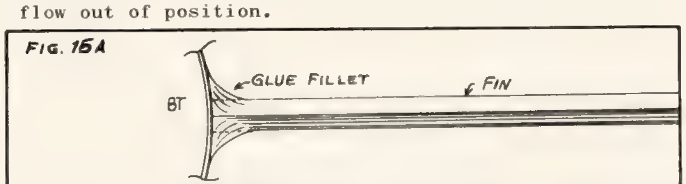


FIG. 15A

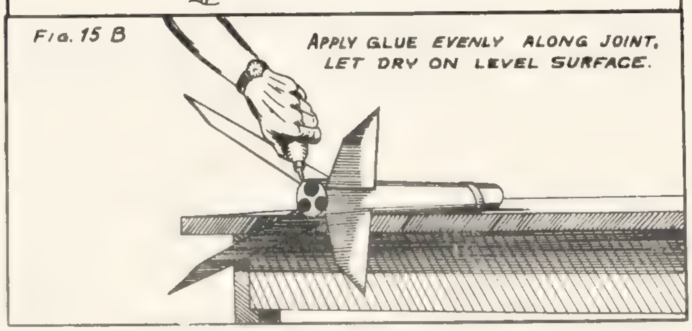


FIG. 15 B

Stability in a model rocket depends on many things, including location of center of gravity, body diameter, nose cone shape, positioning of fins, shape of fins, and surface smoothness. To obtain proper stability in a cluster rocket it is best to make the fins larger than would appear necessary. The center of pressure of a cluster rocket must be at least 1/2 the body diameter behind the rocket's center of gravity (see Technical Report TR-1). If the rocket's stability is tested by the string method described in TR-1, it is best to have at least a 20° margin of stability.

Estes Industries

Guide for Rocket Clubs

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Why Form a Club?

Formation of a model rocket club offers several potential advantages to the members. A club provides the best opportunity to share ideas and to engage in projects beyond the resources or abilities of a single person. In a club the skills of individuals in such areas as electronics, mathematics, rocket design, writing, and physics are available to others so that the group can have activities a single rocketeer would not have the knowledge to carry out. The club offers an opportunity to pool resources to build and operate launching sites and advanced equipment, and to obtain a club laboratory or shop.

The club which has a responsible adult advisor or sponsor can obtain community approval and support much more readily. This is especially valuable in communities where model rocketry is still new to the greater part of the population. By organizing a club, it becomes much easier to gain publicity necessary for community recognition and support.

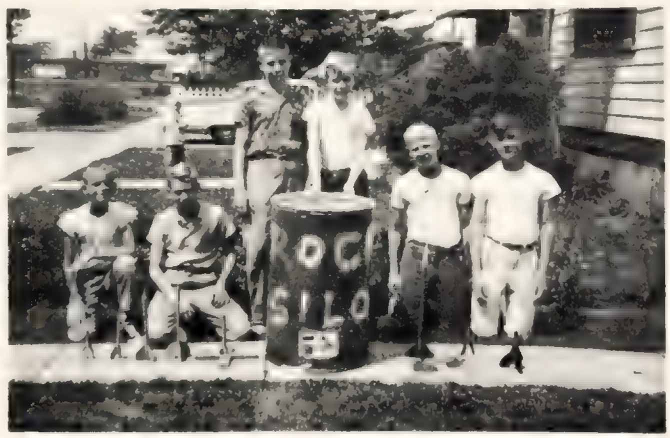
Organization of a club provides an unexcelled chance to participate in many different activities. Among other things, the club can conduct contests, develop research programs, obtain and show films, sponsor educational activities, and give demonstrations. By organizing, of course, the club can compete with other clubs in the areas of altitude, duration, and similar contests, as well as in special research programs to develop and apply scientific devices.

Organizing the Club

The first step in organizing a club is to get several individuals interested in model rocketry. The informal activities of a few persons can serve as a basis for getting more persons interested in model rocketry. Try to find an adult sponsor or advisor who is interested in rocketry. The sponsor can be either an individual or a group. The best bet for a sponsor or advisor is the father of one of the members of the club. If several of the fathers can be interested, it will be even better, since model rocketry is an activity which can be enjoyed by adults as well as young people, and several adults can usually accomplish more in working with the club and the community than one alone. (The adult members don't need to be scientists or rocket experts, either.)

If it is impossible to obtain the father of one of the members for an advisor, there are undoubtedly several civic organizations in the area which will quite possibly be interested. Such groups as the Lyons Club, city recreational committee, Rotary Club, Optimists Club, lodge, and grange, as well as school science teachers, church groups, and aero-space firms, if approached properly, will often be quite willing to help the club form, support it, and provide the needed adult help in its regular activities.

When approaching an adult group for support, the best thing to do is to explain what model rocketry is, the difference between the model rocketeer, the "Basement Bomber," and the amateur rocketeer, the educational and recreational possibilities of model rocketry, the "safety first" attitude in model rocketry, the safety record now established, why the group is organizing, and why the support of an adult group is desired. If the approach is made in a diplomatic manner, the chances are that the club will receive the enthusiastic support of the adult group. Even in the first group approached does not feel that it is possible for it to help the club, persistance in contacting other groups should pay off quite well. If a direct approach to the various civic organizations in the community doesn't get results, try an appeal through the local newspapers.



The neighborhood group can be a good start in organizing the club. Imagination is important here.

The most important single item in forming a model rocket club is to develop a sound system of organization. The accompanying constitution is only a suggested form, and the individual circumstances of the group should be carried foremost in mind when adopting a club constitution. The organization of the group should provide for a democratic system of government, orderly meetings, reasonable membership policies, sound finances, and interesting activities.

The first step in organizing the club is to bring together as many interested persons as possible for a meeting. A temporary chairman and secretary should be chosen, and someone should explain the reasons for the formation of the group immediately. A count should be taken to determine if enough people are actually interested in participating in the club to make formation practical. In order to have an actual club, there should be at least six members, although an organization of fewer persons is possible. For a really active group, ten or more members is a desirable figure for which to aim. The larger the group, the more activities can be held. Those interested should then be signed up as members, and the meeting can proceed to the adoption of a constitution or a set of by-laws. So that this can proceed smoothly and rapidly, a suggested constitution should be prepared ahead of time, and presented to the meeting for adoption or alteration and adoption. The group should elect a first set of officers at the first meeting. A secretary and a president are the two most important officers for the club during the

organizational period, and the best possible persons for these positions should be chosen. Before the close of the meeting a suitable time, location, and date should be chosen for the next meeting. Time permitting, the first group activity should also be selected and organized.

Conducting the Meeting

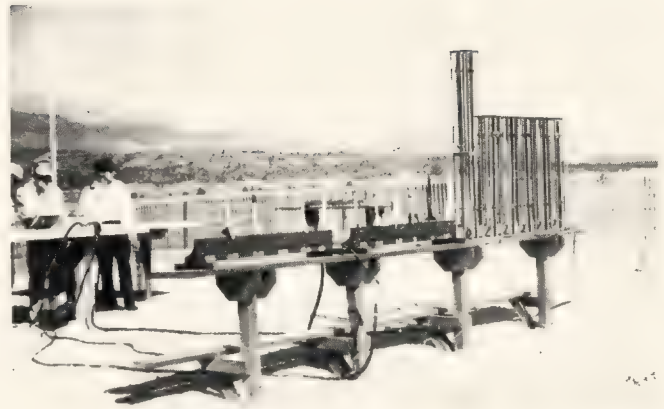
The meeting should begin on time. Failure to do so regularly will result in a later starting time each meeting, until finally no one will show up. The meeting is called to order by the president, followed by the reading of the minutes and the treasurer's report. Next, old business, matters left over from previous meetings, is considered, and when all of it has been attended to, new business in handled. The meeting can either be adjourned at a preset time or when all business has been taken care of.

In conducting a meeting it is important to remember that everything must be handled in an orderly fashion. When the president calls the meeting to order, all private conversations are to cease, and until the close of the meeting, members speak only when called on by the president. Business may either be brought up by the president or by a member when recognized by the president. The normal procedure is to discuss a matter briefly, then have a motion and a second to the motion, followed by a brief discussion of the motion, and then a vote on the motion. Some motions such as a motion to adjourn, to postpone consideration of a question to a future meeting, or to vote on a previous motion do not require discussion, and should be voted on immediately.

In conducting a meeting, two motions should never be on the floor (under consideration) at once unless the one affects the other. So if a motion has been made to hold a rocket launching on Saturday the 24th at 2 pm, the only other motions which would be in order before a vote has been taken on this motion would be: (a) A motion to amend the previous motion. For example, "Mr. Chairman, I move that the previous motion be amended to read "Saturday the 24th at 1 pm." The motion to amend, if seconded, is discussed, then voted on before the vote on the original motion. (b) A motion to postpone discussion. For example, "Mr. Chairman, I move that the previous motion be tabled until the next meeting." If this motion (which requires no discussion) is seconded and passed, discussion on the previous motion is ceased until the next meeting, and the group goes on to discuss other matters. (c) A motion to close discussion. For example, "Mr. Chairman, I move the previous question." This motion is to be voted on immediately, without discussion, and without a second. If passed, then the original motion is voted on immediately, and if the "secondary" motion is not passed, discussion on the original (primary) motion is resumed.

A motion which is not seconded within a brief period "dies for lack of a second." That is, it is dropped from consideration. Note the wording used in the motion: "Mr. Chairman, I move that. . ." This is the proper form for a motion to take, and is required by most major organizations, as it helps eliminate confusion by forcing the rest of the motion to take a logical form. It is highly incorrect to say: "I make a motion. . ," both grammatically and as far as the rules for conducting meetings are concerned. It is recommended that the president of the organization study a copy of Robert's Rules of Order, available at most public libraries. It might also be wise to appoint a club parliamentarian, whose duty it will be to study the rules of order and advise the group on correct procedure whenever necessary. In fact, a point of order (the calling of attention of the group to some irregularity in procedure) is the only thing which can be done without recognition by the chairman. If a member of the club is proceeding contrary to the established rules for conducting meetings, any other member may interrupt with a point of order, and if the point is actual, it must be followed.

Disorder, horseplay, and the like during the business meeting should not be permitted, as they make it im-



Launching sites such as this can be built by an active club. The facilities pictured are part of a range designed to accommodate up to 100 rocketeers in a contest.

possible to accomplish anything, make the meeting dull and boring, and can eventually cause the entire organization to fall apart. A sergeant-at-arms may be appointed to enforce the rules of the club, even, if necessary, by expelling disorderly members from the meeting.

Duties of Officers

The club president is responsible for conducting the meetings in a business-like manner. He should come to the meeting with an agenda (list of items of business) already prepared, should start the meeting on time, guide the discussion, and terminate it if it should become stalled or pointless. It is also the president's duty to make sure that all members have an equal opportunity to speak, and he should prevent the overly talkative members from monopolizing the meeting. Much of the success the club meets will depend on the ambition and ability of the president.

The club vice-president (if there is such an office in the organization) is responsible for conducting the meetings in the absence of the president. In addition, the club constitution may give him other duties, such as attending all committee meetings, organizing contests, and the like.

The club secretary is responsible for keeping the minutes (record) of all meetings and conducting all club correspondence. The minutes are a step by step record of the proceedings of the meeting, and should contain all matters discussed and all motions, whether passed or defeated. A good secretary is necessary if the club is to be able to operate smoothly from one meeting to the next.

The club treasurer is responsible for all club funds. The treasurer takes care of the collection of dues, the purchase of equipment, the saving of money, and the maintaining of an exact and continuous record of all income and expenditures. Generally club funds should be kept in a bank account, and either the signatures of both the president and treasurer or of the advisor and treasurer should be required for the withdrawal of funds from the bank and the purchase of equipment. No money should be spent without the approval of the club.

Other club officers may be elected or appointed as necessary. These may include a quartermaster to take charge of all club supplies, a range captain to conduct all rocket launchings, a public relations officer to handle publicity, etc.

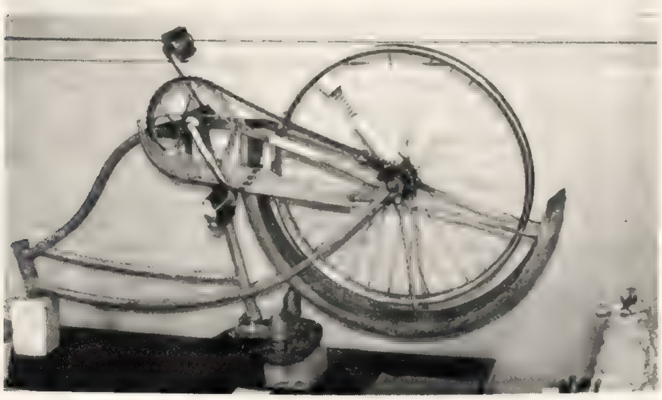
Club Activities

The number of activities a club can hold is limited only by the imagination and ambition of the members. Regular flight days should be held at which the members can test their designs and get altitude data. Contests

can consist of several events, flown at the same time or following each other. Competition is usually held in the areas of altitude, duration, scale, and design. Most of these events were originated by the National Association of Rocketry, and if your group wishes to concentrate on the competitive aspects of model rocketry, it may well be desirable to affiliate with the NAR. Altitude contests are held with models using the same number and type of engines, such as B Altitude in which the models use only one B engine, or A-1/2A Altitude, in which the models are two staged, with A.8-0 boosters and 1/2A.8-4 upper stages. With the many different types of engines now available, a large variety of altitude events is possible.

In running an altitude event, it is necessary to have a fairly accurate optical altitude tracking system, communication between the trackers and the firing officer, and competent data reduction personnel. A variation in altitude events is provided by the requirement that the model carry a payload, usually a one ounce lead cylinder 3/4 inches in diameter. Other rules for altitude events can be determined by the club or its contests and records committee.

There are two common types of duration events, boost-glide duration and parachute duration. To run a duration event it is necessary to have at least one timer with a watch with a sweep second hand. The timer should have a stop watch, although this is not necessary, and two official timers will help make the results more accurate. The rocket is timed from the instant of ignition to the moment the first part of the rocket, other than wadding or the engine, touches the ground. In boost-glide duration the rocket must ascend in a vertical flight under power and return in an aerodynamic glide. A typical boost-glider is the Astron Space Plane. In parachute duration the rocket must be returned to the ground by a parachute. In both events, should the rocket go out of sight the timers stop their watches, and may restart them should the rocket appear again.



Research equipment need not be expensive. Apparatus such as this centrifuge for testing payloads may be built for just a few dollars.

In scale events the rocket must be a scale model of an actual guided missle or space vehicle, and is judged on the workmanship, trueness to scale, and flight characteristics, as well as on other points which the club may choose. It is generally best to require that the contestant supply data along with his model to show that it is an actual scale model.

Special events include such things as drag races, in which two rockets are launched simultaneously, and one point is given to the model which achieves first motion, one point to the model achieving the lowest altitude, and one point to the model which touches the ground last. Drag races are run in paired heats, in normal tournament order. Another special event is spot landing, in which the rocketeers, using a launcher which is adjustable for angle of launch, attempt to land their rockets as close as possible to a preset point on the ground. In this event it is necessary to require that the models contain a safe recovery system, that they be launched within 25° of the vertical, and that their recovery systems deploy at least 50 feet from the ground. For variety, an event can be organized in which rocketeers attempt to fly their rockets as close to a predetermined altitude as possible. For example, if the altitude is 1000 feet, a person whose rocket climbs to 990 feet might be declared the winner, with second place going to the person who got 980 feet, third to 1030 feet, etc. Still more events can be dreamed up by the club, such as Egg Scale Altitude, in which the entry is judged on scale, with achieved altitude added to the scale points, and must carry a grade A large hen's egg in its payload section in flight to qualify, returning the egg undamaged if it is to place. A simpler event might be Odd Ball Streamer Duration, in which the rocket would receive from 1 to 100 points for its oddness, to which its duration in seconds is added to determine the final score.

Design contests can be held to determine the best design in a preset category--single stage, multistage, boost - glider, etc. Judging in these events must be carried out by a person who is not himself a contestant to insure that all designs are judged fairly.

To add extra incentive for participation in contests, points should be given for flying and for placing in an event, these points being accumulated over the year, with the person gaining the most points during this period declared the club champion rocketeer. Points should be assigned on a scale which gives a special advantage to the winner of an event. For example, 6 points might be given for first place, 3 for second, 2 for third, and 1 point for making an official flight in the event. In case of a tie, equal points should be given each person.

Research programs make excellent club projects. One project, for example, could be the design, construction, and use of a high speed wind tunnel for measuring drag on model rockets. Another could be the design of special purpose rockets for payload applications, or the group could specialize in the design of boost-gliders, multi-stage rockets, camera rockets, or special launch facilities. An area which has great potential is in the design and fabrication of electronic equipment such as radio transmitters to withstand the strains of launching with Series II engines, making the components small and light enough so that the equipment does not impair the performance of the rocket.

The club should have a library containing as much useful information as possible. In addition to the information available in the Estes Industries Catalog, such magazines as Science Digest, Scientific American, and Popular Science, as well as some of the many different publications available from the U.S. Government Printing Office, Washington 25, D.C. will be especially valuable in a club library. A file containing rocket plans, especially plans of all rockets built and flown by club members will also be useful. A club librarian should be in charge of the organization and maintenance of the library, and should catalog the library's contents so that selection of material will be easier. For information on running a library, talk to the librarian of either the school library or the public library.

From time to time there will be opportunities for the club to sponsor educational programs for others. A good project might be demonstration of the principles of space flight at a local school, or perhaps it might be possible for the club to hold an assembly on rocket safety in the school. Here again, the imagination and ability of the group will determine the possibilities of the activity.

Above all, in holding club activities it is necessary to remember that the club itself must dream up, organize, and carry out the activity, without depending on others for a step-by-step explanation. One of the major requirements of the scientist is that he be able to decide on a project by himself, locate needed information by himself, and do the work by himself. If he can meet

these requirements, he is then ready to contribute to the activities of the group. The same standards hold true for the scientific organization as for the individual.

Constitution of the West Podunk Rocket Research Society

ARTICLE I: NAME

The name of this organization shall be the MODEL ROCKET RESEARCH SOCIETY of West Podunk, Colorado.

ARTICLE II: PURPOSE

It shall be the purpose of this organization to develop the art of model rocketry through the pursuit of such research programs as the members shall feel useful, and to implement these research programs through the holding of regular contests between society members, through the creation and maintenance of a society library, and through the operation of a society research laboratory. It shall further be the purpose of this organization to aid the cause of rocket safety through educational programs designed to acquaint the public with the high degree of safety gained through following the Model Rocket Safety Code, in contrast with other, non-model, forms of rocketry.

ARTICLE III: MEMBERSHIP

The membership of this organization shall consist of all interested persons, regardless of age, who express a desire to join, pledge to follow the Model Rocket Safety Code, and who pay promptly all dues monies as assessed by the society at its regular meetings.

ARTICLE IV: MEETINGS

Meetings of the Model Rocket Research Society of West Podunk shall be held at least 26 times per year and at such times and places as the membership shall approve by a two-thirds majority vote. Operation of the society rocket range shall not be considered a meeting. A quorum of one half the membership shall be necessary for the transaction of any business, and all meetings shall be conducted according to Robert's Rules of Order, Revised. Consistent failure to attend society meetings without proper reasons shall be considered cause for the dismissal of a member from the society, subject to review by the society Executive Board.

ARTICLE V: OFFICERS

The officers of this organization shall consist of a President, Vice President, Secretary, and Treasurer. The Executive Board of the society shall consist of the four above officers, an adult member who shall be appointed as society advisor, and one elected member-at-large for every twelve members or major part thereof. Officers and Executive Board members may be removed from office by a two-thirds vote of the entire membership.

ARTICLE VI: ELECTIONS

The election of officers and Executive Board members shall take place at the first meeting of the calendar year. Nominations shall be submitted by the members in the meeting, and voting shall be by secret ballot. A candidate must receive at least one half of the votes cast to be elected. All officers and Executive Board members shall serve terms of one year. Vacancies in offices shall be filled by the nomination and election of a society member to fill the vacant office for the remainder of the term, and such nomination and election shall take place at the society meeting at which the vacancy is announced.

ARTICLE VII: DUTIES OF OFFICERS

1. President:

   It shall be the duty of the President to preside at all society meetings, to serve as an ex-officio member of all committees, and to represent the society at public affairs.

2. Vice President:

   It shall be the duty of the Vice President to preside at society meetings in the absence of the President, to serve as chairman of the Range Operations Committee, and to serve as director of the Library Committee.

3. Secretary:

   It shall be the duty of the Secretary to take minutes at all meetings, to handle all society correspondence, to serve as chairman of the publicity committee, and to keep a file of all minutes and correspondence.

4. Treasurer:

   It shall be the duty of the Treasurer to collect all society dues, to keep records of all income and expenditures, to keep all society funds safe, and to manage the purchase of equipment, etc., for the society upon authorization by its members.

ARTICLE VIII: COMMITTEES

There shall be four Standing Committees of the society, and such additional committees as the society Executive Board may from time to time consider necessary. The Standing Committees shall be:

1. Range Operations Committee:

   The Range Operations Committee shall be in charge of the building, operation, and maintenance of a society firing range and the equipment necessary for it. Members of this committee shall be responsible for the enforcement of safe conduct on the firing range.

2. Laboratory Committee:

   The Laboratory Committee shall be in charge of the research work of the society, including the obtaining of equipment, the procuring and maintaining of the laboratory building or room, the assignment of research duties, the recommendation of projects to the society, the enforcement of safe procedures, the compiling and publishing of research results, and the education of society members in the correct approach to research in the scientific method.

3. Library Committee:

   The Library Committee shall be in charge of the procurement of all necessary reference material for a complete library, the establishment of lending policies for the society library, the collection of money, if any, assessed for the use of the library, the cataloging of all books and materials according to a suitable system, the care and maintenance of the books and materials connected with the library, and the collection and preservation of published materials dealing with the activities of the society.

4. Publicity Committee:

   The Publicity Committee shall be in charge of notifying the public of any society activities which may be of general interest or value, the editing and publishing of a regular society newspaper or magazine, and the arranging of all society demonstrations and educational programs for the public.

ARTICLE IX: AMENDMENTS

This constitution may be amended by a two-thirds majority of the members of the Model Rocket Research Society of West Podunk, Colorado, present and voting at any meeting of the society, provided that such proposed amendments were distributed in written form to all society members at least seven days in advance of the meeting. The society Executive Board may veto any amendment, but if, at the next regular meeting of the society, the veto is announced and a simple majority of those present vote to override the veto, the amendment shall go into effect. The amendment shall also go into effect if the Executive Board shall fail to announce its veto at the first regular meeting following the original vote on the amendment.

Bring 'em Back - - Gently!

The parachute offers one of the simplest, most effective recovery methods available to the model rocketeer. At the same time it is often misunderstood, misapplied and mistreated. Experience has shown that the principles and methods described here are reliable with both single and multi-stage rockets provided the model itself is built correctly.

Parachute Materials

While practically everything from bed sheets to balsa has been tried for making parachutes, three materials, paper, silk and plastic, dominate the field. Paper is inexpensive but not durable, so it is of limited value for model rocketry. Paper parachutes rip easily when hit by high velocity air and do not unfurl as rapidly or reliably as plastic or silk when packed in small diameter body tubes.

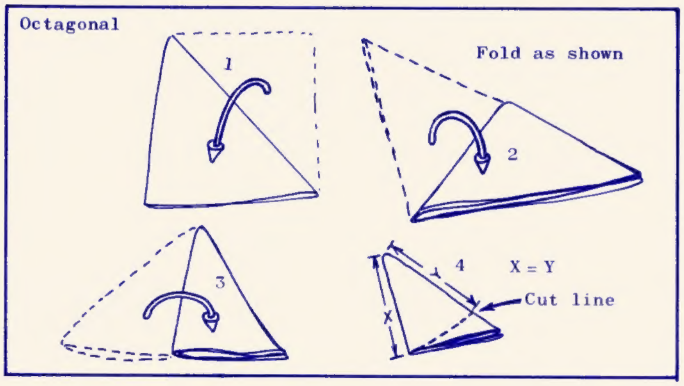
Silk is an excellent material for model rocket parachutes, but combines disadvantages with its good points. While it is light, will not take a "set" easily and is extremely strong, it is also expensive and a difficult material to handle in construction. Loose silk threads have a habit of tangling and preventing the parachute from opening, so it is necessary to sew all edges of the fabric into tight seams to get proper operation. Shroud lines should be sewed directly to the silk.

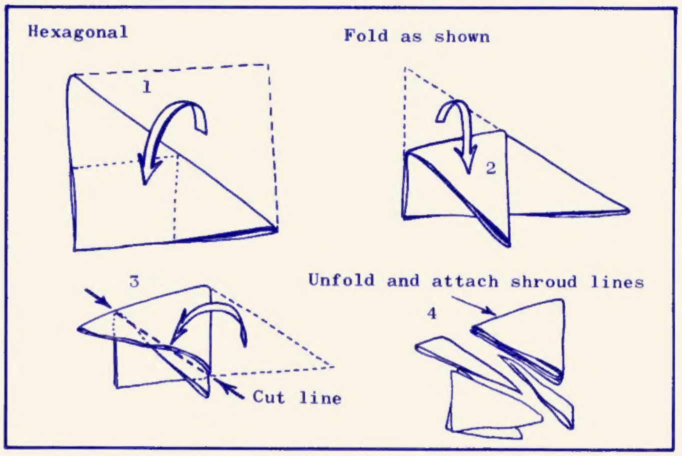
The most widely used parachute material for model rockets is plastic. Combining the virtues of low cost, durability and versatility, it is available in an almost unlimited range of colors, thicknesses and sizes. The types of plastic used for parachutes are for the most part those sold especially for model rocket use and the plastic bags used by cleaners to protect clothing. Plastic thickness generally ranges from .0015" to .0005". For normal use .00075" is the minimum recommended thickness. The main disadvantage of plastic is its sensitivity to heat. The parachute must be well protected from the ejection charge.

Shroud lines are important to the operation of any parachute. Experience has shown that smooth, hard surface material such as carpet thread is best. Shroud line length should be sufficient to allow the parachute to open fully. Generally the proper length will be between 3/4 and 1 parachute diameter (for example, between 9 and 12 inches for a 12 inch diameter parachute).

Parachute Shape

The most common parachute shapes are square, round, hexagonal and octagonal. While square parachutes are the easiest to make, they are not very efficient and allow a considerable amount of sway during descent. Round parachutes are fairly stable in descent, but are more difficult to make. The hexagonal and octagonal parachutes are highly stable, reasonably easy to make and generally give the best appearance. The accompanying drawings illustrate methods for making these shapes.





Parachute Size

For best results a parachute should have at least 38 square inches of area for each ounce of rocket weight. Thus the maximum weight for a 12 inch parachute will be about 3 ounces. Less area may be used on very light rockets, since they will gain less momentum than larger models. On the other hand the upper limit on parachute area can be determined only by considering desired duration, landing softness, weather conditions and opening reliability.

For small, lightweight rockets extra-small parachutes are often advisable since these models can reach extreme altitudes and drift considerable distances even in gentle breezes. The 38 square inches per ounce formula can be used to determine the parachute's size, but experience will be a better guide.

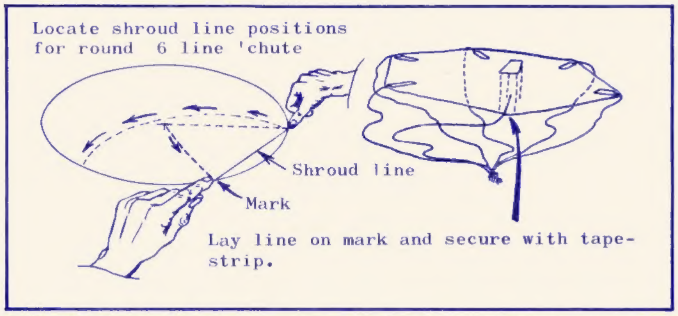
The effective area of a standard commercial parachute can be reduced in several ways. The shroud lines may be shortened or two lines taped together at the top to keep the parachute from opening completely. The center of the parachute may be cut out or the two color printed parachutes (PK series) may be cut on any of the inside circles to form smaller parachutes.

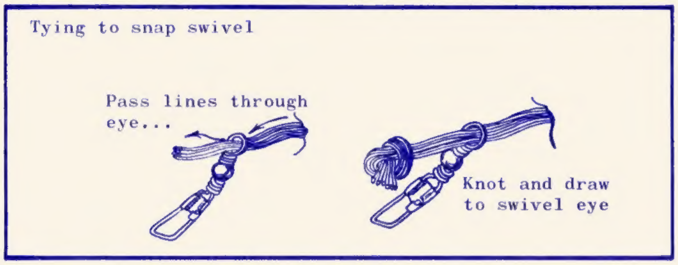
The opposite extreme in parachute size becomes important in duration contests. In such a contest a large, lightweight parachute is important to obtain the lowest possible descent rate. The area to weight ratio must be very high. Competitive duration models have ratios of from 300 to 500 square inches per ounce for calm weather. Models equipped like this can turn in times of 10 to 20 minutes.

Parachute Assembly

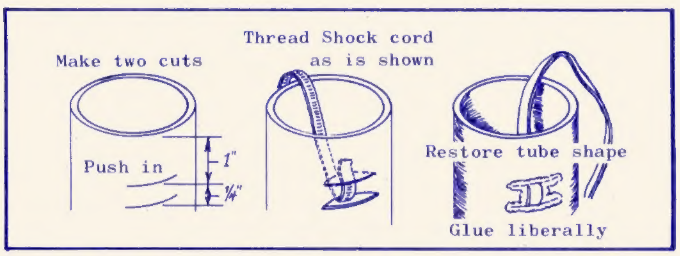
After cutting the parachute to shape as in the preceding section shroud lines are attached either by tying or by using tape discs or strips. Tape strips are generally the most satisfactory since they are easy to use, light and strong. When shroud lines have been attached to the parachute and cut to the proper length they can either be attached directly to the rocket or attached to a snap swivel. (The use of a snap swivel offers a definite advantage since different parachutes may be selected for various flying conditions or the same parachute may be used in several different rockets.)

The parachute is ejected from the rocket body in flight with considerable force and generally opens quite suddenly. This





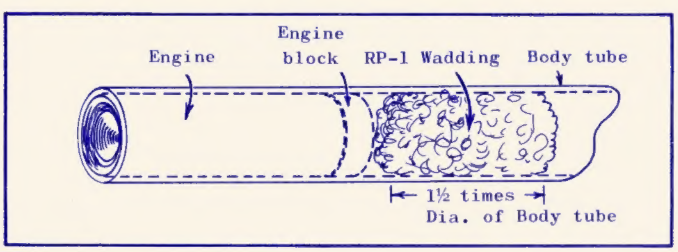
shock must be absorbed so shroud lines, etc. are not broken. A length of shock cord (model airplane contest rubber) is connected between the parachute and the main part of the rocket. The shock cord is attached to the rocket body by cutting two slits,



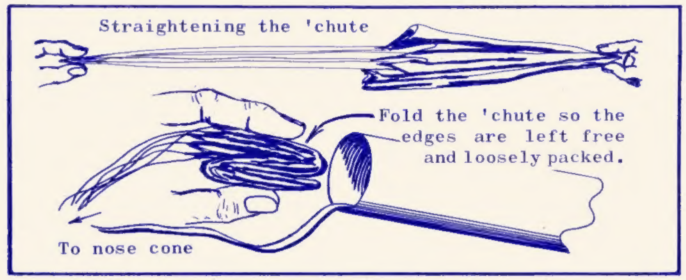
passing the end of the cord through the slits and gluing as shown in the drawing. The free end of the shock cord is then attached to a screw eye in the base of the nose cone. The parachute can then be attached directly to the nose cone if the cone weighs less than 1/2 ounce. If the nose cone weighs more than 1/2 ounce there should also be a length of shock cord between it and the parachute.

Parachute Packing

When preparing a rocket for flight it is extremely important to protect the parachute from the heat of the ejection charge. The most reliable and effective way of doing this is by filling the body tube for a distance equal to 1-1/2 times its diameter with flameproof tissue, cotton or recovery wadding. The wadding serves as an insulating layer between the parachute and the engine and as a gas seal and piston to insure that the ejection charge works evenly against the parachute and nose cone.



When the wadding has been placed in the tube, dust the parachute lightly with talcum powder to keep it from sticking to itself when packed in the rocket body. Next form the parachute into a spike shape as shown, fold once or twice to make it fit the space available in the body tube and insert it into the tube. Pack the shroud lines and shock cord in over the parachute and push the nose cone or payload section into place.



It is interesting to note that elaborate, precise and exacting methods for folding model rocket parachutes have been proposed and used, but the most reliable recovery comes with the somewhat sloppy system described above. Current theory holds that this reliability is the result of the tendency of the material to spring back somewhat when crumpled and the ability of loose corners, edges and folds to catch the breeze.

For parachute duration contests special attention to packing, secure shroud line attachment, etc. is important. The rocket's body tube should be large enough to hold the parachute and wadding without squeezing and yet small enough to keep the rocket's weight as low as possible. B. 8-2 and B. 8-4 engines are generally recommended for use in duration events.

The Time Factor

The period the parachute spends packed in the rocket while awaiting flight has a considerable effect on reliability. Plastic has a special tendency to take a "set," especially when cold. As a general rule the parachute should remain packed no longer than 1 hour in warm weather, 1/2 hour when the temperature is between 40° and 60°, and no more than 5 minutes when the temperature is 32° or less. In cold weather it is a good idea to prepare the rocket in a heated area and keep it warm until just before launching. If the parachute is in the rocket longer than the period recommended it should be removed from the rocket body, opened up, refolded and repacked before flight.

If these steps are followed carefully, parachute recovery can be highly reliable, spectacular and useful. It will prove its value again and again in demonstrations, payload launchings, contests and sport flying, and will provide an excellent basis for further experiments into rearward ejection, side ejection, booster recovery and many other special systems.

Engine Mounting

Ejection gases must pressurize the parachute compartment of a model if the parachute is to be ejected. If the engine is loose in the body it will be expelled rather than the parachute. If there are any holes the gas can leak through, it will, and the rocket will streamline in.

Use plenty of masking tape to hold engines in place. Wrap the engine with tape even if a wire engine holder is used to retain the engine, since an air-tight seal is needed. It is practically impossible to have the engine held in place too tightly.

Wind

Never fly rockets in high winds, since aerodynamically stabilized vehicles fly into the wind and will present a hazard if they take paths parallel to the ground. In addition, a parachute recovered rocket will drift for a considerable distance at the same speed as the wind. Thus in a 20 mile-an-hour breeze the model will drift at 20 mph--considerably faster than a normal person can run. In more moderate winds it is still important to use caution, but rockets can be flown without great difficulty if parachute size is kept within reasonable limits set by the weather conditions and rocket performance.

ESTES Industries, Inc.
Devoted to Safety and Education in Rocketry

Box 227,
Penrose, Colorado

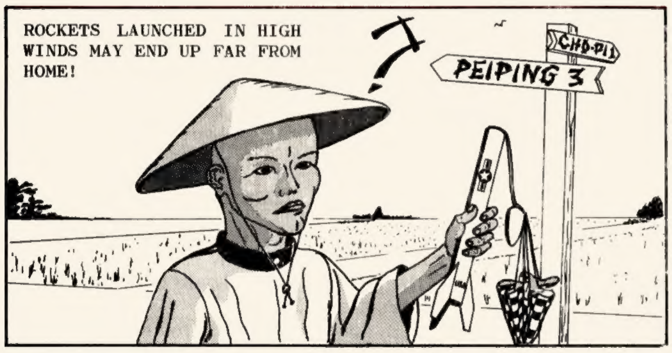
Model Rocket Engine Instructions

WARNING

Read these instructions carefully before using, working with or igniting any model rocket engine.

SAFETY RULES: These engines should be used only on devices which are specifically designed to perform properly with the type of engine being used. Engine mounts and materials surrounding the engine should be of non-metallic substances such as paper, plastic, wood, etc. Never launch a rocket which does not have a recovery system to break the aerodynamic stability of the model for the return flight. Always launch rockets in a vertical direction only, using a suitable launching system which will guide the rocket until it has enough speed to stabilize itself. Do not launch models in high winds, in the vicinity of flying aircraft, near tall buildings or trees.

Always store engines in a cool, dry place. Do not subject them to heat greater than 150 degrees F. Do not in any way tamper with or attempt to alter the engine casing, propellant, nozzle, etc., and do not use any engine which shows signs of damage. Never attempt to reload an expended engine casing. Care should be taken when hooking up igniters to keep fingers and body away from the nozzle. Under no circumstances should the nozzle be aimed toward the face. Stand at least 10 feet away from any rocket engine when it is being operated. Do not smoke near rocket engines and do not store them near highly combustible materials. Due to use, storage and other conditions beyond our control, no warranty is either made or implied as to the performance or reliability of these engines.



ROCKET ENGINE SELECTION: Rocket engines produced by Estes Industries are designed for flying recoverable, lightweight model rockets. For single stage usage the primary engines are the 1/2A. 8-2, the A. 8-3 and the B. 8-4. For selecting special performance engines and for additional design and technical data see the complete rocket engine selection chart in our current catalog.

SECURING THE ENGINE IN THE ROCKET: Different rockets are designed to hold their engines in various ways. Always follow the model manufacturer's recommendations when mounting the engine in the model. Parachute and streamer recovered models require special care in mounting the engine. When the ejection charge is activated, the inside of the model is pressurized. If the nose cone, parachute and wadding resist this pressure more than the engine does, the engine will be ejected, the parachute and nose cone will stay in place and the rocket will streamline in, probably damaging it. To prevent this, the engine must fit tightly. A good fit can be obtained by wrapping the engine with masking tape as shown in figure 1.

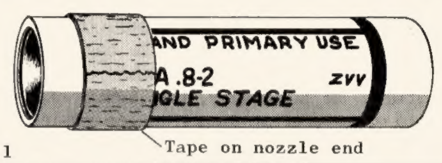


Fig. 1

Always be sure the engine is mounted securely so its thrust will not move it forward in the rocket body. Extra care must be taken when mounting a Series II engine in the model. The engine block or engine holder must be securely glued in place. Be sure a force of ten pounds will not move the engine forward in the body. The engine should be positioned so its nozzle end is no more than 3/8" forward from the end of the body tube.

IGNITION: Model rockets are to be launched by electrical means only. Electrical igniters are supplied with all engines sold by Estes Industries. These igniters consist of a nichrome wire with an extra high resistance section in the middle. Surrounding this high resistance area and extending out slightly along the leads of the igniter is a plastic coating which serves as electrical insulation to prevent the igniter from touching itself and short circuiting. In addition, the coating will burn when it is heated to 1100° F. The igniter is installed in the model rocket engine so its coating touches the end of the propellant grain. When an electrical current of 2 amperes or more passes through the igniter the high resistance area heats to 1100°, igniting the coating which in turn ignites the engine immediately.

CROSS-SECTION OF ELECTRICAL IGNITER

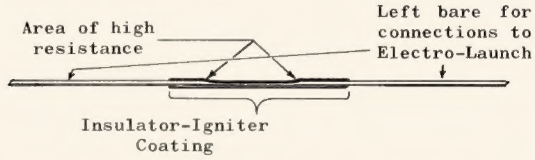


Fig. 2

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INSTALLING THE IGNITER: Estes igniters are supplied in strips of three. Cut the igniters apart (scissors will work) midway between the coated sections. Bend the igniter at the middle as shown in figure 3 and push it into the engine as far as it will go. To operate properly the igniter must touch the propellant grain. Wad up a 1" square of kleenex and place it into the nozzle between the igniter leads. Be sure the igniter leads do not cross or touch each other. Tamp the wad into the nozzle with a pen or pencil to hold it and the igniter firmly in place.

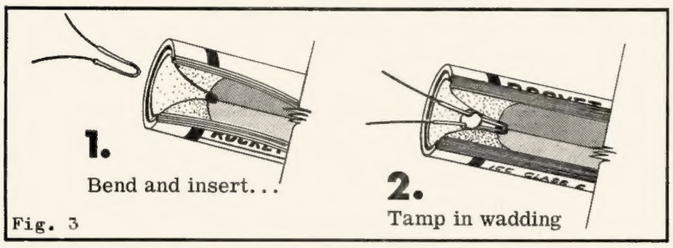

Fig. 3

PREPARING FOR LAUNCHING: Always double-check the recovery system of your model before launching. Parachute and streamer recovered models should have enough wadding between the engine and recovery system to prevent scorching the parachute or streamer and assure positive ejection. Usually the wadding should fill the tube for a distance of at least 1-1/2 body tube diameters.

Slip the model's launch lug over the launch rod and lower the rocket into position on the launcher. Make sure the micro-clips on the launcher are clean, then clip one to each lead of the igniter. The clips must not touch each other and the igniter leads must not cross. If necessary, the rocket may be supported with a scrap of wood or an empty engine casing to make it easier to attach the clips and to keep the clips from touching the metal blast deflector and short circuiting.

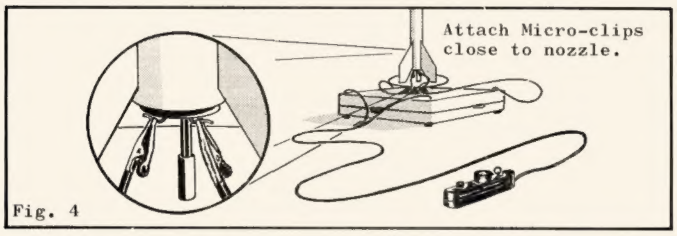

Fig. 4

COUNTDOWN: For greater realism and safety a countdown should always be given before launching a rocket. First, arm the launch panel. Then begin counting: "5—4—3—2—1—Launch." Press the switch at "launch." If the batteries are in good condition the engine will ignite immediately. As the batteries get weak there will be a short delay between the time the button is pressed and the engine ignites. Disarm the panel as soon as the rocket takes off.

MISFIRES: Occasionally the igniter will heat and burn in two without igniting the engine. This is almost always caused by failure to install it correctly. If this occurs, disarm the launch panel, remove the model from the launcher, clean all pieces of igniter and wadding from the nozzle and install a new igniter properly. Follow the normal launching procedure again.

If the launcher's electrical system is defective or the batteries are too weak the igniter may not get hot enough to operate. In this case, remove the model from the launcher, connect the clips to a 2" piece of #30 nichrome wire or a light bulb of the correct voltage and check all contacts until the wire or light glows. If all contacts check out and the launcher still does not deliver power, try fresh batteries. When the problem has been corrected replace the model on the launcher and try again. The power supply must be strong enough to force at least 2 amperes of current through the highly resistant igniter. When the current is low it will take the igniter several seconds to heat. A power supply that can force 6 to 12 amperes through will give the best results. The power supply should produce at least 6 volts to do the job quickly and efficiently.

TYPES OF LAUNCHERS: Figure 5 shows a typical launcher circuit. The system should be constructed so the control panel is at least 10 feet from the launcher. The interlock is provided to prevent accidental launching of the model. The pilot light is placed in the circuit so that when the interlock is closed the light will glow if there is a complete electrical circuit through the igniter. If the light does not glow, the circuit is not complete and the engine will not ignite when the launch switch is pressed.

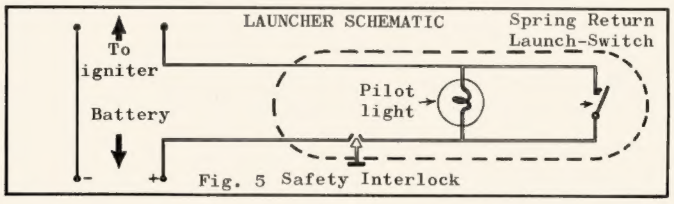

Fig. 5 Safety Interlock

Many model rocketeers prefer to design and build their own launching systems. Others prefer to use a commercial kit. The most popular launcher kit is the Electro-Launch manufactured by Estes Industries. For additional details, consult our current catalog of model rocket supplies.

Figure 6 shows a simple home made launching system. This system requires at least 12 feet of 18 gage, 2 conductor wire, a spring return launch switch (a door bell button will work), a suitable launching stand with a 36" long 1/8" diameter launching rod, two battery clips, two micro-clips and a heavy capacity 6 or 12 volt battery. "Hot shot" batteries or car batteries are recommended for this type of system. When using a car battery it is not necessary to remove it from the car.

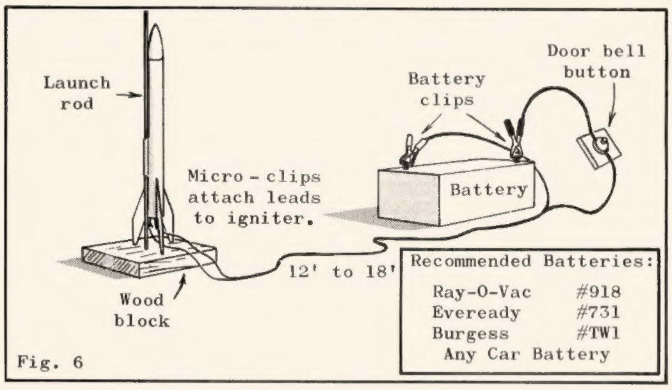

Fig. 6

CLUSTER IGNITION: When igniting more than one engine at a time the igniters should be connected in parallel. To insure simultaneous ignition the power supply should be able to provide at least 6 amperes current at 12 volts for each igniter used. Generally a car battery in good condition is the best power supply. For further information on cluster ignition and building techniques see Estes Industries Technical Report TR-6, Catalog number 641-TR-6, 25¢ each.

MULTI-STAGING: The bottom stage of a multi-stage vehicle is ignited electrically in the standard manner. Booster stage engines are designed to ignite the next engine automatically as they burn out. Full information on multi-stage techniques is contained in Technical Report TR-2, Catalog Number 641-TR-2, 25¢ each.

SAFETY FIRST — Follow the Code

ASTRON ROCKET SOCIETY

SAFETY CODE

As a model rocketeer I will act in a mature manner with safety foremost in my mind in all my model rocket activities and will obey this safety code at all times.

1) I will not attempt to compound propellants or other combustible chemicals or tamper with pre-manufactured rocket engines. I will not use model rocket engines for purposes other than those for which they are recommended by the manufacturer. I will inspect each rocket engine before use and never use an engine which shows signs of physical damage, remembering that any rocket propellant can be explosive under certain conditions.

2) I will not smoke near rocket engines, launch my rockets in the presence of highly combustible materials, use flammable recovery wadding or engage in any activity which would present a fire hazard.

3) I will never use any metallic rocket engines, will not construct my model rockets with substantial metal parts in the area of the engine, and will not launch any rocket over 16 ounces in weight or containing more than 4 ounces of propellant in compliance with Federal regulations.

4) My model rockets will be electrically ignited, using a launch system with either a switch protector or a safety interlock to prevent accidental ignition of the rocket engine, and I will remain at least 10 feet away from any rocket which is being launched. I will use only igniters of the type recommended by the engine manufacturer.

5) I will launch my model rockets using a launching rail or other suitable guide means aimed within 25 degrees of the vertical to assure a safe and predictable flight path, and will launch only rockets whose stability characteristics have been predetermined.

6) I will not fly model rockets in high winds, conditions of low visibility, in the vicinity of low flying aircraft, near tall buildings, near people not aware of the launching, or under any conditions which might endanger property or persons.

7) I will not launch rockets so that their ballistic trajectory will carry them against targets on the ground, and will never use an explosive warhead or other pyrotechnic payload in a rocket.

8) My model rockets will contain recovery devices which will deploy at an altitude of at least 50 feet to return the rocket safely and undamaged. To insure proper operation of my rocket's recovery system I will make a careful pre-launch inspection of all the recovery components with special attention to tightness of the engine and nose cone.

9) To prevent accidental eye injury I will always either place the launcher so the end of the rod is above eye level or cap the end of the rod with my hand when approaching it. I will not place my head or body over the launching rod.

10) When conducting research activities with unproven designs or methods I will, when technically possible, determine their reliability through pre-launch static tests, and I will conduct launchings of unproven designs in complete isolation from persons not participating in the actual launching.

(Revised 1/1/65)

REMEMBER: Model Rocketry makes an excellent father-son activity. Both enjoy it and the mature thinking of an adult will assure maximum safety and pleasure from your rocket activities.